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TIDAL CURRENT ATLAS FOR LONG ISLAND SOUND AND SAN FRANCISCO BAY--ETC(U)
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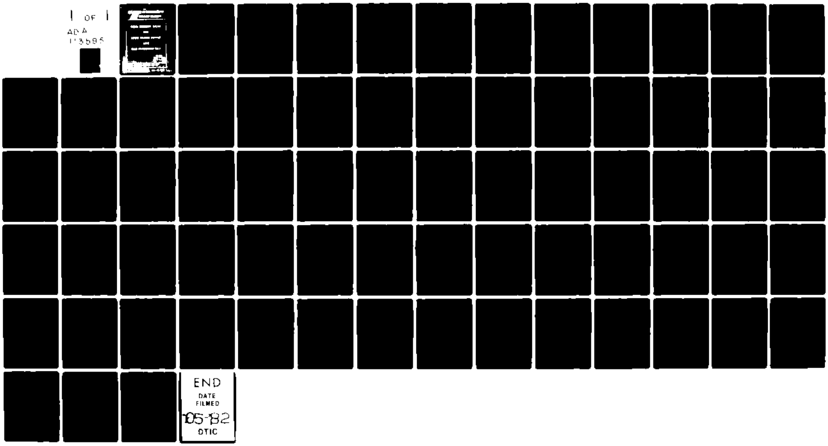

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TIDAL CURRENT ATLAS FOR LONG ISLAND SOUND AND SAN FRANCISCO BAY

BY

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ABSTRACT

A computerized Tidal Current Model for Long Island Sound and San Francisco Bay has been developed by the Coast Guard Oceanographic Unit. The model is a digitized version of the National Ocean Survey's Tidal Current Tables and the Tidal Current Charts for Long Island Sound and Block Island Sound and San Francisco Bay. Test were conducted to verify the accuracy of these sources of Tidal Current information using a drift pole survey of surface currents for Long Island Sound published by the Coast and Geodetic Survey and The Army Corp of Engineers Hydraulic Model Bay and Delta Model for San Francisco. The Long Island Sound test showed complete agreement between the model and observations 83.2% of the time, and 100% agreement at 40% of the positions tested. The San Francisco Bay test showed under prediction of speeds by 0.5 to 1.0 knots in 3 of 4 regions and over prediction by 0.6 knots in the 4th region. The predicted directions were deflected to the right of the oberved directions 75% of the time by 49.15 - 66.11° . These comparisons indicate that the data for Long Island Sound is reliable and that for San Francisco Bay should be used with caution.

A

TABLE OF CONTENTS

	Page
Title Page	i
Abstract	ii
Table of Contents	iii
List of Illustrations	iv
List of Tables	v
Introduction	1
System Description	2
Special Features of Long Island Sound	4
Verification of the Long Island Sound Program	6
Discussion of the Long Island Sound Program	9
Conclusion on the Long Island Sound Program	9
Special Features of San Francisco Bay	11
Verification of the San Francisco Bay Program	13
Comparative Method	13
Discussion	28
Conclusions	29
Appendix I	31
Appendix II	35
Appendix III	38
Appendix IV	49

LIST OF ILLUSTRATIONS

Page

Figure 1a. The currents (in knots) for an example station from *LITSF and* Lalachur and Sammons (1932).. 10

Figure 1b. The directions of the currents from LITSF and Lalachur and Sammons (1932)................ 10

Figure 2. Overall view of San Francisco Bay.. 14

Figure 3a. Northern San Francisco Bay and San Pablo Bay LITSF grid and test stations.................. 15

Figure 3b. Southern San Francisco Bay and San Pablo Bay LITSF grid and test stations.................. 16

Figure 4. LITSF and Hydraulic model tidal curves for 10/11 March 1977 at the Golden Gate......... 17

Figure 5. LITSF and Hydraulic model tidal curves for 14/15 May 1977 at the Golden Gate............ 18

Figure 6. LITSF and Hydraulic model tidal curves for 16/17 October 1977 at the Golden Gate...... 19

LIST OF TABLES

Table 1a. Geographical grouping of sampling stations in San Francisco Bay for analysis 20

Table 1b. Regional values form statistical and general comparison between computerized and hydraulic model of San Francisco Bay. Speed in knots, Direction in degrees.................. 21

Table 2. Statistical and general analysis values for the far regions of Figure 2...................... 24

Table 3. Variations in direction in the four regions of Figure 2................................ 25

Table 4. Variations of magnitude in the four regions of Figure 2 25

Table 5. The standard error range for direction in the four regions of Figure 2..................... 25

Table 6. Percentage of high and low magnitude values relative to the mean. Percentage of left and right occurence relative to the mean 26

INTRODUCTION

An automated system for providing tidal current information for Long Island Sound and San Francisco Bay has been developed for use in the Coast Guard's Search and Rescue (SAR) planning and in Marine Environmental Protection (MEP) such as forecasting pollutant drift. The system is a digitized version of the National Ocean Survey's tidal current charts for Long Island Sound and San Francisco Bay. The new system is an updated version of the original system developed by Morgan et al. (1974) for Long Island Sound with San Francisco Bay added. The objectives of these systems is to provide tidal current information for use with the Computer Assisted Search Planning (CASP) in a timely manner. The current values generated are the tidal currents and estuarine flow. They do not include currents generated by any other environmental parameters.

Long Island Sound is classified by Swanson (1975) as having a semidiurnal tide with a slight diurnal inequality. The inequality in the range is reflected in the magnitude of the ebb and flood tide currents. In San Francisco Bay there is also a diurnal inequality which is more pronounced than it is in Long Island Sound. This makes for a greater variation in the magnitude of the ebb and flood tides occurring during a single tidal day, 24 hours and 50 minutes. That is to say the flood tides in a given day may have significantly different magnitudes. The same, of course, is true of the ebb tides. This inequality is produced primarily by the lunar declination and is independent of whether the moon is north or south of the equator. The diurnal inequality has a maximum magnitude at approximately 14 days intervals (Defant 1961 and Disney et al. 1925). This diurnal inequality in the magnitude of tidal currents makes long term drift forecasting a very tedious process. It is necessary to update drift forecast positions at intervals of one hour or less and to make multiple runs of the tidal current program to obtain the correct tidal vectors.

The average period for the flood tide in Long Island Sound is 5.9 hours and the average period for the ebb is 6.6 hours based on the month of January 1975. By dividing the flood tide into six equal periods and the

ebb into seven equal periods, a total of thirteen tidal hours of approximately equal length can be produced. These tidal hours are 0.98 and 0.94 solar hours in length for the flood and ebb respectively. As a result the time steps may be treated as equivalent to solar hours.

The flood tide in San Francisco Bay is longer than the ebb tide, 6.71 hours versus 5.71 hours (Disney 1925). Even with this inequality of ebb to flood time the tidal sequences are divided into equal intervals for both sequences. These tidal hours are roughly equilavent to solar hours being 1.12 hours for flood and 0.95 hours for ebb.

SYSTEM DESCRIPTION

The tidal currents are obtained from the National Ocean Survey tidal current charts: San Francisco Bay 6th edition 1973 and Long Island Sound and Block Island Sound 6th edition 1977. These charts are based on direct current measurements with Roberts Current Meters and Richardson Current Meters (Hicks, 1967). The horizontal distribution of the current vectors in these charts is too random to permit the needed precision required in Coast Guard SAR and MEP applications. To overcome this weakness current values were interpolated between known values and a more complete array developed.

The resultant current vector arrays have a horizontal resolution of 2 x 2 nmi. This is 2' of latitude by 3' of longitude in Long Island Sound and 2' of latitude by 2.5' of longitude in most of San Francisco Bay and San Pablo Bay. In the approaches to the Golden Gate and the parts of the Bay near Angel Island, Treasure Island, Yerba Buena Island and Alcatraz Island the horizontal resolution is 1 x 1 nmi or 1' of latitude by 1.25' of longitude.

To use the models an operator needs certain parameters which are used by the computer model to calculate the tidal currents. These input parameters are the local date, time and position. The position is given to the nearest minute for Long Island Sound and the nearest 0.25 minute for San Francisco Bay. The output of the program is the tidal current speed and direction in degrees true and knots plus the tidal cur-

rents at the reference station for the date of occurrence. The Long Island Sound currents are referenced to the Race and the San Francisco Bay currents are referenced to the Golden Gate.

The computer program LITSF, which is used to generate the tidal currents, is a computerized version of (a) the annual Tidal Current Tables published by the National Ocean Survey for the East and West coast and (b) the Tidal Current Charts, also published by the National Ocean Survey. The main part of the program is the National Ocean Survey's Tidal Current Prediction Program which is used to generate the tidal current information in (a). The Tidal Current Charts have been digitized and stored on a disk file in the computer's memory. These files are accessed by a subroutine, SLACK, in the program.

When a date, time, and position of occurrence is fed into the compute, the program uses the date to calculate the tidal current information for the reference station in the Tidal Current Tables. This information is then used by the subroutine SLACK to generate the correct tidal current for the time and place of occurrence. In short the computer is doing the same steps as a man using the two references above in generating a tidal current vector.

A listing of the program, digitized tidal current charts and an explanation of how the charts are digitized are included in Appendix III.

SPECIAL FEATURES OF LONG ISLAND SOUND

The tides in Long Island Sound are co-oscillating tides displaying a mixture of standing wave and progressive wave characteristics. The loss of energy due to bottom friction is such that only a partial reflection of the tidal wave occurs. This is most clearly seen in Long Island Sound in the increased amplitude of the western end of the sound. The primary tidal current and tidal waves enter the eastern end of Long Island Sound through the Race. The tide belatedly enters the Sound from the west by way of New York's Hell Gate. This tends to dampen the flood and ebb currents in the western end of the Sound. As the tide enters Long Island Sound through the Race frictional forces retard its propagation through the area. There are very strong currents in the area of the Race reaching speeds as great as 5.3 knots (272.8 cm/s) during ebb and 4.3 knots (221.3 cm/s) during flood. High water requires an hour to travel or extend from Montauk Point to the Race and three and a half hours to extend into the relatively small Peconic Bays to the south of the Race. The lag from Montauk Point to Throgs Neck is three hours. As a result the flood current begins at the eastern end of the sound and moves progressively westward. The currents at any given point in the Sound reach their maximum midway between slack water times.

The high current speeds in the region of the Race require frequent updating of the position of the drift object to obtain the most accurate tidal current information. For example, a 4.3 knot (215 cm/sec) current will carry a drifting object form one 2 x 2 nmi grid square through a second and into a third in one hour. Therefore, it is necessary to put in a corrected position at thirty minute intervals to insure use of the correct tidal current vector in forecasting the drift of an object.

Another area of interest in SAR/MEP planning is on the south side of Long Island Sound between Northport, 73°20'W and Stony Brook, 73°10'W. In this area there occurs a counter current during most of the flood tide. This counter current flows eastward with speeds of up to 0.5 knots (25.5 cm/s). There is a weak extension of this counter current as far east as Port Jefferson, 73°03'W during the latter stages of the flood

tide. A similar westward flowing counter current forms during ebb tide in the same area. Great care should be taken in establishing the start position for drift forecasting in these areas. If the position is not known with certainty, then alternate start positions should be considered.

VERIFICATION OF THE LONG ISLAND SOUND PROGRAM

The assumption upon which the LITSF program is based is that current vectors obtained from Roberts Current Meters at depths of 10 to 15 m may be used for surface tidal currents. To test the validity of this assumption, the tidal current vectors in the LITSF program for Long Island Sound are compared with surface tidal current vectors obtained by a current pole survey in Long Island Sound (La Lacheur and Sammons 1932). The current poles were 15 ft. (4.6 m) long and weighted at one end so that they floated vertically with 1 ft. (0.3 m) sticking out of the wate.. The pole is allowed to drift for a time with a line attached to the upper end. The length of line which pays out is taken as equal to the distance the pole had drifted. This is divided by the drift time to determine the speed. The direction is determined by observation from the survey ship. This method gives a vertically integrated measure of the upper 4.3 m ?auer current, both tidal and estuarine flow.

The accuracy of the direction of drift observation made with current poles is estimated to be ± 20° and the accuracy in magnitude to be no better than ±0.2 knots (10 cm/sec). The Roberts Current Meters have a ±10 cm/sec accuracy in magnitude (Hicks 1967). Agreement between the two measurements is defined as occurring whenever the error bars overlap. That is to say, whenever the direction is within 30° the precision of the measurements does not allow us to identify any real difference. Similarly whenever the speeds were within ±0.4 knots (20 cm/sec) it was not possible to identify any significant difference in the magnitude of the current. Ten stations were selected for examination. They were selected as areas where one might expect the tidal current program to give poor results. As a result the test sample is not a random sample and should in fact give a worst case evaluation of Long Island Sound. The surface currents recorded by La Lacher and Sammons (1932) are average currents for a one year period. They are compared to the yearly averages of the currents in the Long Island Sound Program.

Station 1. At Throgs Neck, 41°54'N, 73°40'W, the speed and direction values were in agreement 100% of

the time. A graphical representation of the magnitudes and directions is given in Figure 1 of this section.

Station 2. This station is located at 40°56'N, 73°27'W is midway between the northern and southern shores at the western end of the Sound. The speed of the current and the direction of the LITSF program agree with the test observations 100% of the time.

Station 3. This station is located on the southern shore at 40°58'N, 73°06'W. This station is in the area where a back flow was predicted in the LITSF program. The surface observations also show evidence of the back flow. At station 3, however, the observed flood is one hour longer than the flood tide predicted by the LITSF program, and the ebb is one hour shorter. This produces significant differences in the direction for a period equal to 1/4 of the tidal cycle. If the directions are disregarded, then the magnitude agrees to the precision of the observations. This back flow appears to be the result of bottom and/or sidewall interaction with the flow. It varies with depth and very probably varies significantly in the horizontal as well.

Station 4. This station is located on the southern shore at 40°56'N, 72°45'W. At this station there is also a back flow in the surface, but it is different from that at station 3. That is, the observed surface flood tide is six hours long and the observed ebb is seven hours long. The LITSF program flood is 7 hours long and the ebb is six hours long. As with the observations at station 3 this back flow and temporal variation is probably due to boundary layer effects. The errors in the LITSF program could only be corrected by a detailed current meter project in the area. The magnitude of the currents is in agreement 85% of the time at this station, and if the currents are averaged over the entire tidal cycle they agree to the precision of the measurements. The observed currents are twice as large of the LITSF program currents for 15% of the time, one hour during each ebb tide.

Station 5. This station, located at 41°08'N,72°45'W is near the geographical center of Long Island Sound. The magnitude of the observed surface currents and the LITSF program currents are in agreement 100% of the time to the precision of the measurements. There is not, however, a similar agreement in the direction.

The LITSF program currents are 30° to the right of the observed surface currents during the flood tide and 30° to the left during the ebb tide. That is, the LITSF currents were northwest and northeast of the observed surface currents. This was the worst case for directional agreement and the only one with complete disagreement.

Station 6. The observed surface currents and the LITSF currents at this station, 41° 14'N, 72°42'W, agreed in both magnitude and direction 100% of the time.

Station 7. This station is off the mouth of the Connecticut River at 41°16'N, 72°21'W. The directions agree within the precision of the measurements. The direct observations of the surface currents, however, show that on the surface the current begins to ebb about one hour before it does at the mid-level depth of the current meter used to generate the tidal currents for the LITSF program. Such vertical variations are not uncommon in river channels and at the mouths of rivers. The directions agree to the precision of the measurement, except for the last hour of flood.

Station 8. This station is located midway between the northern and southern shores at the eastern end of Long Island Sound at 41°04'N, 72°15'W. The observed surface currents and the LITSF program currents agree in magnitude and direction 100% of the time.

Station 9. This station is on the Connecticut shore just west of the mouth of the Themes River at 41° 16'N, 72°06'W. The LITSF program currents agree in direction 85% of the tidal cycle. The magnitude agrees with surface observations throughout the flood tide, but on the ebb tide the LITSF program currents are 180% of the observed values. This overestimation lasts for three hours or approximately 23% of the total tidal cycle. As in the case of station 7 these changes are primarily due to the effects of the river outflow.

Station 10. Station 10 is at the Race, 41°14'N, 72°03'W. The LITSF program currents agreed in direction 92% of the tidal cycle when compared with surface observations. The LITSF program currents were faster, 110%, than the observed values during the flood. During the ebb currents, the LITSF program currents

were 90% of the observed surface currents. The differences amounted to a half a knot in absolute values on the average.

DISCUSSION

Although this test was designed to give a worst case view of the LITSF program, it showed that complete agreement in speed and direction was observed 83.2% of the time. At 40% of the stations the agreement was 100% of the time. Only one station was off for the entire tidal cycle. That station was 30° off in direction for the entire tidal cycle. Disagreement appears to occur most often near the coast and/or near river mouths. In both cases, the influence of the bottom topography and variable river flow are large. The bottom topographic features such as sand bars are also subject to a relatively slow variation with time. This makes correcting the model for such influences a very difficult process and one of limited value. Because both the LITSF values and the current pole survey are direct current observations, the differences are to some extent a measure of the natural variability in the currents.

CONCLUSIONS

The use of mid level current observations to infer surface currents is apparently a valid assumption. It is recommended that the currents from the National Ocean Survey Tidal Current Charts for Long Island Sound be used.

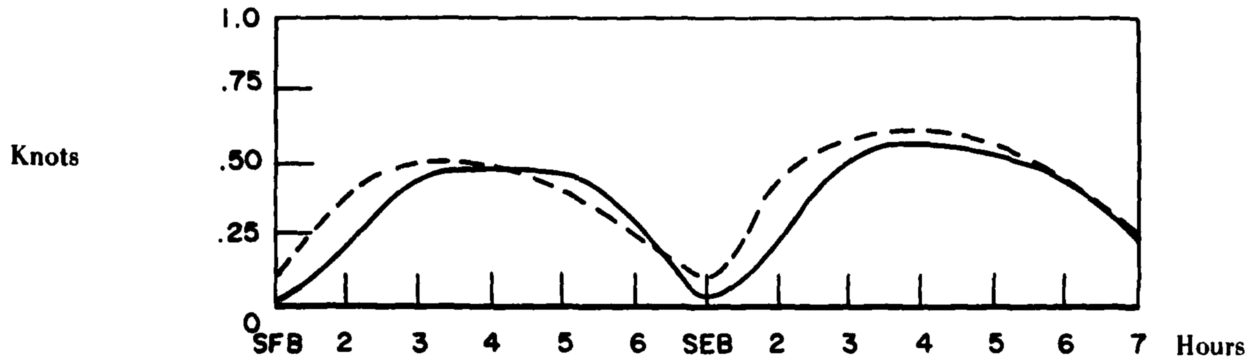

Figure 1a. The currents are given in knots --- *La Lacheur and Sammons* LITSF *currents.* SEB - Slack Water Ebb Begins at the Race. SFB - Slack Water Flood Begins at the Race.

	LaLachear	LITSF
SFB	050	055
2	---	234
3	235	235
4	240	235
5	230	236
6	230	235
SEB	235	060
2	---	058
3	050	058
4	055	055
5	060	055
6	050	063
7	050	063

Figure 1b. The directions are given in degrees true

SPECIAL FEATURES OF SAN FRANCISCO BAY

Although San Francisco Bay is an extensive embayment, it possesses only one entrance located at the Golden Gate region (Figure 2). In addition to this restricted entrance, the bay can be divided into two distinct tidal regimes; a standing and a progressive tidal wave. The Golden Gate and Southern Bay region, contain a tidal scheme similar to a standing wave, as evidenced by simultaneous changes in the tide throughout the area (Disney et. al. 1925). The northern bay region and San Pablo Bay exhibit a progressive wave phenomenon. This occurance shows up as a progresively later flood or ebb current as one moves north to San Pablo Bay. The time of occurance of these currents also lags the southern regions' current changes.

In the San Francisco Bay system, friction is the most significant factor modifying the tidal currents. This shows up vividly in the Golden Gate area (bounded by (1) 37° 48'N - 122° 22.5'W (2) 37°50'N 122°32.5'W (3) 37°48'N 122° - 32.3'W and (4) 37°50'N - 122° 22.5'W) as a very pronounced horizontal current variability. This variability presents itself as a set of eddies formed by lateral friction on the northern and southern shores near the western approach to Golden Gate. These eddies produce near shore counter currents on both the ebb and flood tides. As a result, a drifting object near shore and just seaward of the Golden Gate Bridge may travel westward on a flood tide or into the bay on an ebb tide. This feature makes it extremely important to know the initial position and start time for any SAR case when predicting a drift path.

The duration of flood and ebb tides as well as the magnitude of the currents is also found to be variable within the bay. The flood to ebb duration was found by Disney (1925) to be 6.71 hours to 5.71 hours (1.18:1). This ratio persists throughout most of San Francisco Bay with the exception of San Pablo Bay where the influence of river run off causes a revised ratio. Also, in the northern portion of the Bay and San Pablo Bay, the initial flood current is sub-surface wand moves vertically to the surface, while the ebb exhibits the reverse (Disney 1925). The magnitude of the currents through the Bay at times exceeds 2 knots

(102.1 cm/sec). In an area of great horizontal variability, they may be as high as 4 knots (204 cm/sec.

To model the San Francisco Bay current fields with the above noted variability, a flexiable grid pattern and set time interval were selected. In areas of high current variability, a small grid square (1 x 1 nautical miles) was utilized, while a larger grid (2 x 2 nautical miles) was set up in the rest of the Bay (Figure 3). Even with the noted inequality of the ebb to flood time, the tidal sequence was divided into equal time intervals. These modeled tidal hours are equivalent to solar hours set at 1.12 hours for the flood and 0.95 hours for ebb. These parameters of grid size and time interval, do however, require that in drift studies the calculated tidal current vector be updated on an hourly basis or less if in an area of high currents.

VERIFICATION OF THE SAN FRANCISCO BAY PROGRAM

To establish the validity of the total current vectors calculated by the San Francisco Bay computer program, comparisons between calculated and measured values were made at fifty one stations in the Bay (Figure 3a and 3b). The measured current values were obtained from the hydraulic tests run on the U.S. Army Corps of Engineers, San Francisco Bay Delta Model, Sausulito, California. These tests were run in May 1978 during a simulation of the 1977 Delta dynamics involving a net river flow (Sacramento and San Joaquin Rivers) of 4700 cubic feet per second (133.09 m /sec), an ocean salinity of 33.00‰ and a 19 year mean tidal curve as the repetitive forcing function near the mouth of San Francisco Bay. The computerized tidal current vectors utilized in the verification were calculated for three, twenty four hour time periods at the fifty one sampling stations. The time periods were selected so that the computer generated currents would be in two catagories: (1) a set in which the tidal height curve near the mouth of the Bay approached the 19 year mean and (2) a set in which the tidal current curve near the mouth of the Bay approached the Delta Model Tidal Current values measured at the Golden Gate Bridge. The first set was obtained from two time periods; 10-11 March and 14-15 May 1977 (Figures 4 and 5) and the second was matched with a period during 16-17 October 1977 (Figure 6).

COMPARATIVE METHOD

The degree of agreement between the observed and calculated tidal currents at the sampling stations was analyzed using portions of the Student-t formula (equation 1, Peterson, 1973) and an hourly comparison of the speed and direction values. Normally, the calculation of the Student-t values for a paired data set would involve the construction of a hypothesis test to determine the probability that the sample means differed by some set value (in this study the value was set at zero in equation 1). However, this course of evaluation would have been inconclusive, because even through the difference in the means approaches

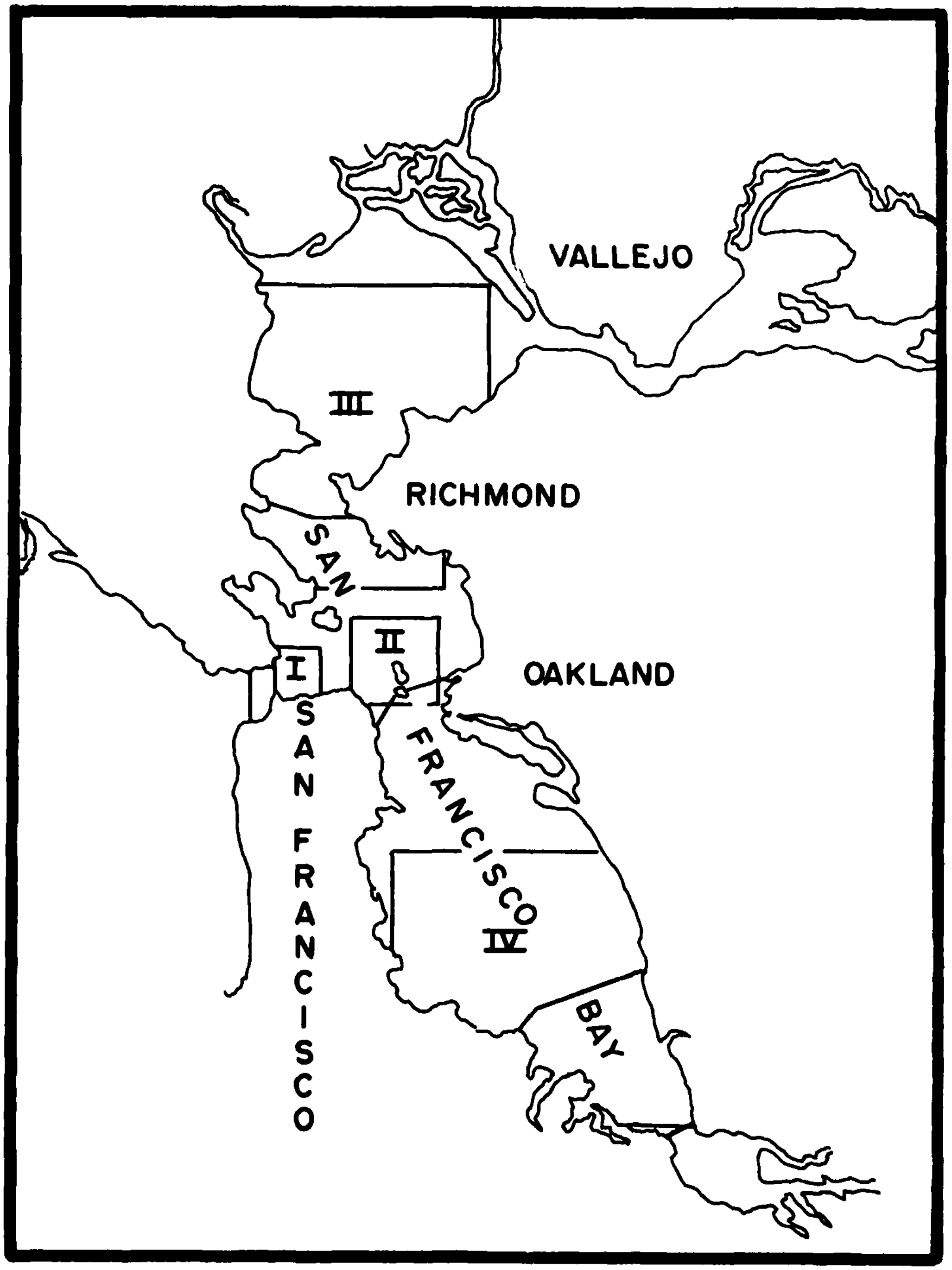

Figure 2. **Overall view of San Francisco Bay - Showing complete system. Heavy Double lines denote Hydroulic Model boundries, I, II, III, IV, denotes current station sampling areas.**

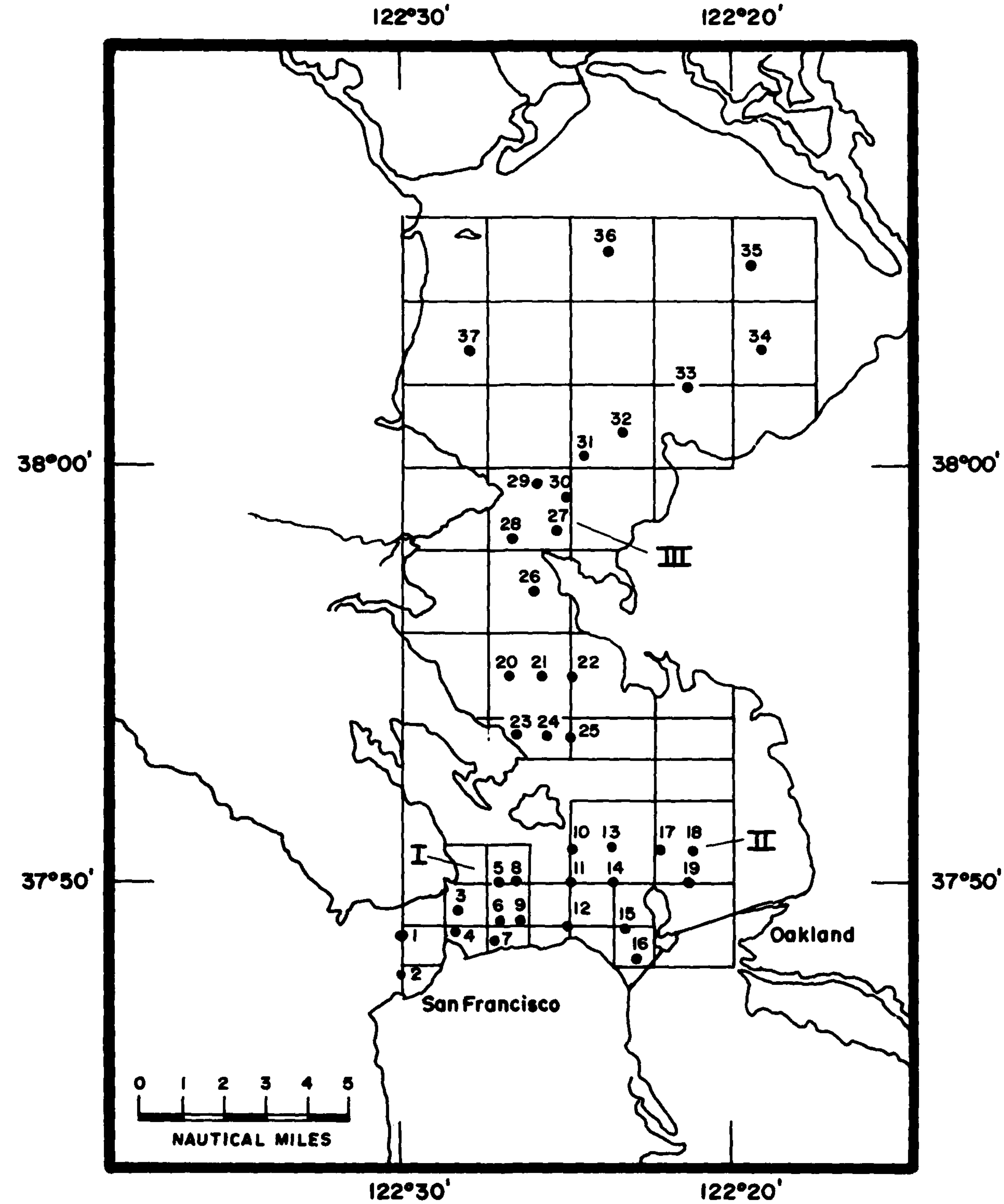

Figure 3a. Northern Section of San Francisco Bay showing partial grid layout of current file and sampling stations 1-37.

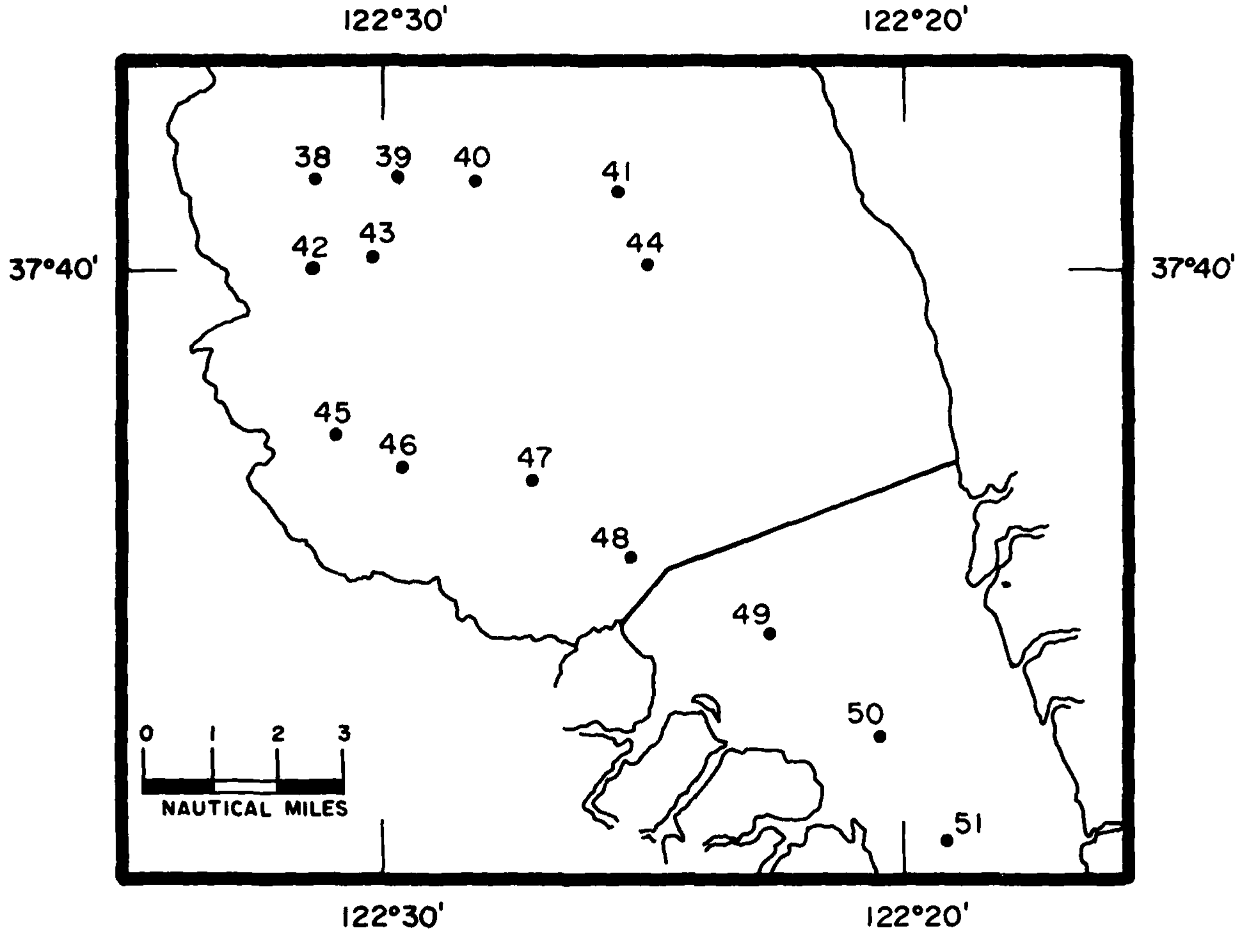

Figure 3b. **Southern Section of San Francisco Bay showing partial grid layout of current file and sampling stations 38-51.**

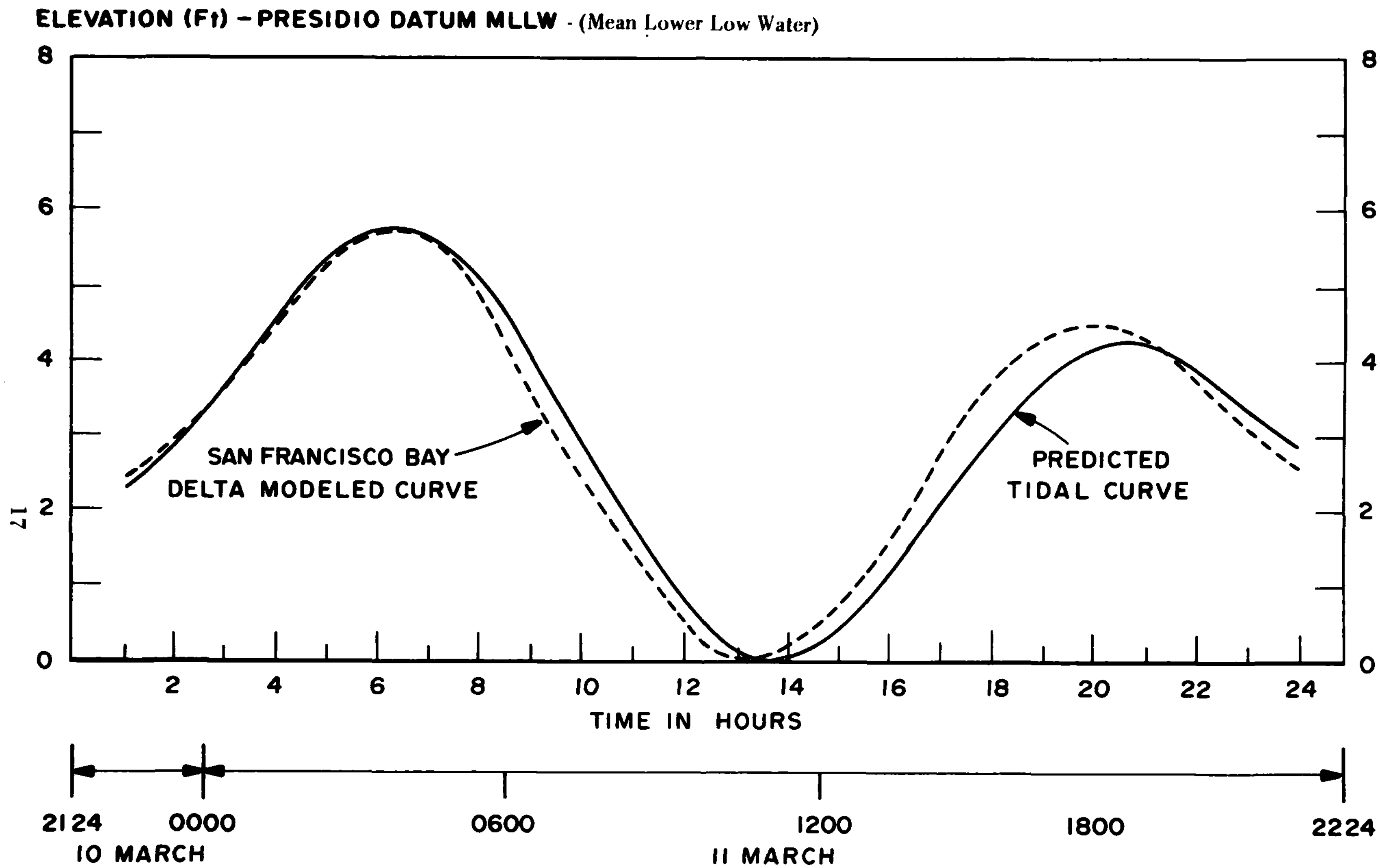

Figure 4. Modeled and predicted tidal height curve at San Francisco's Golden Gate. Modeled curve representes 19 year mean versus predicted curve for period 2124 10 March to 2224 11 March 1977.

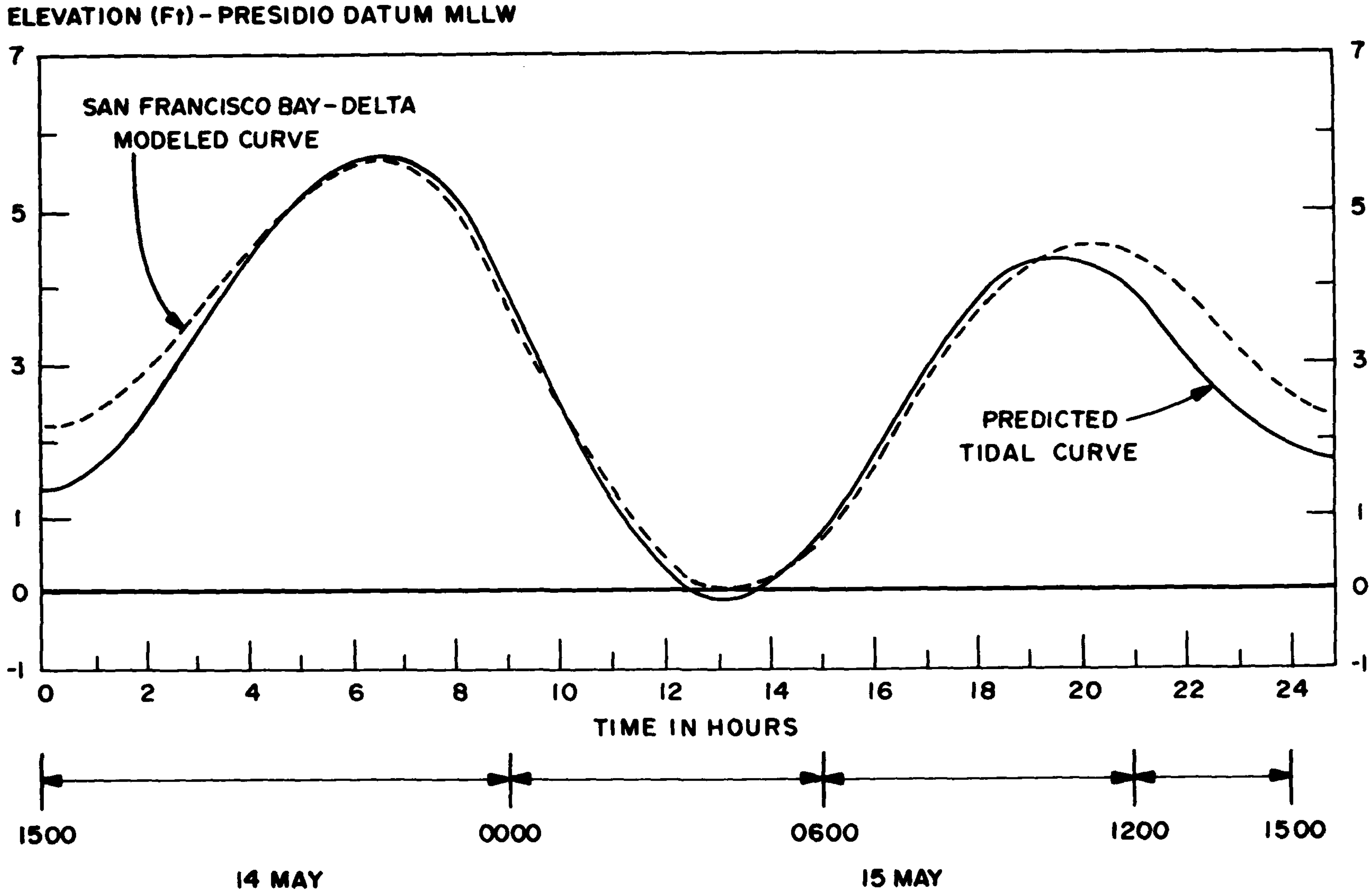

Figure 5. Modeled and predicted tidal height curve at San Francisco's Golden Gate. Modeled curve represents 19 years mean and predicted curve for period 1500 14 May to 1600 15 May 1977.

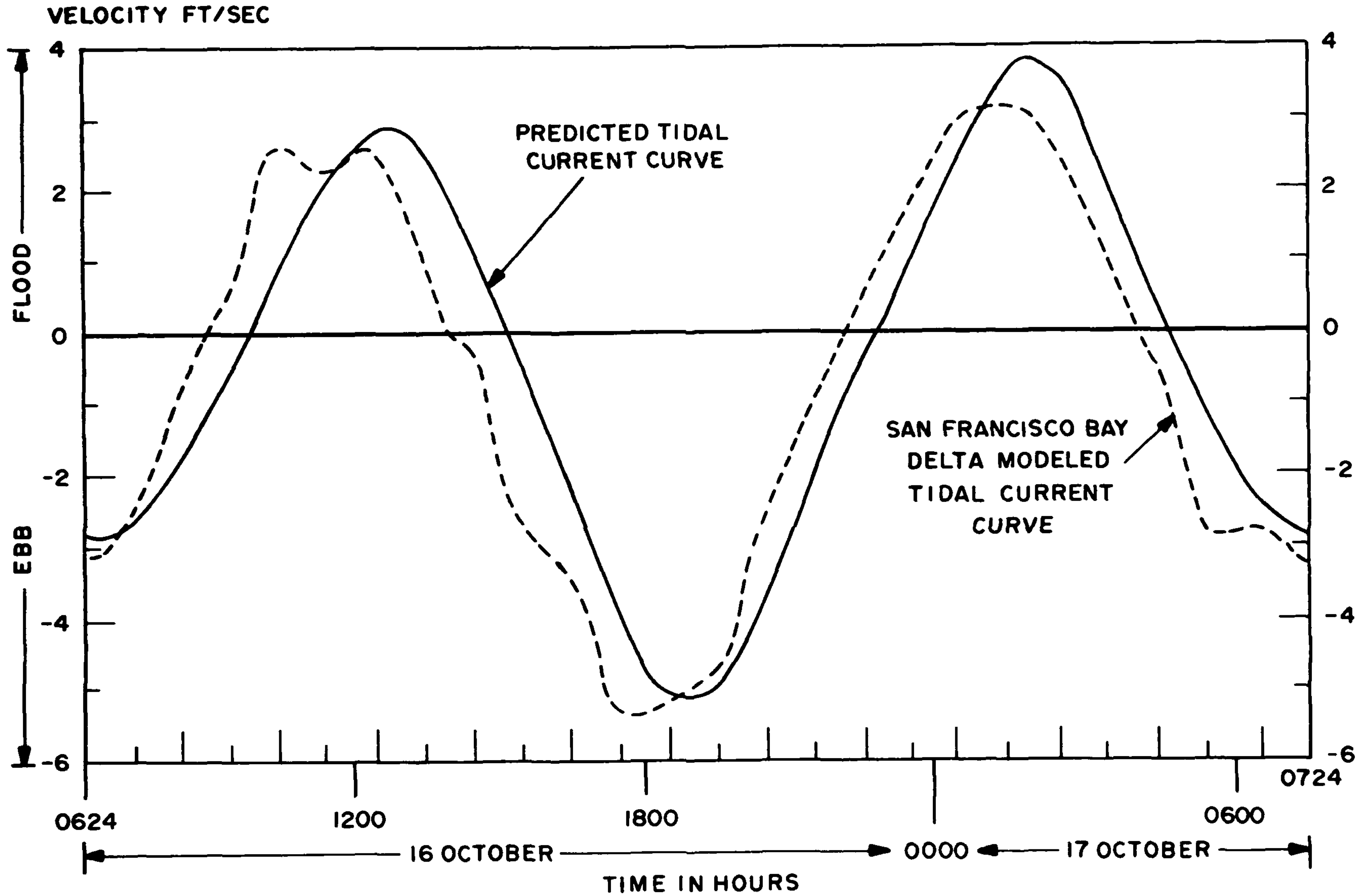

Figure 6. Modeled and predicted tidal current curve at San Francisco's Golden Gate. Modeled curve represents measured values from Delta Bay Hydroulic Model 1977 Delta experiment and predicted curve for period 0624 16 October to 0724 17 October 1977.

The standard deviation (B) was then used to calculate the standard error:

$$C = \sqrt{1 + \frac{1}{n_1 + n_2}}\ [B] \qquad (2)$$

where:

$\sqrt{1 + \frac{1}{n_1 + n_2}}$ the adjustment value required when using the standard deviation in the calculations.

(B) = the standard deviation from equation 1

(C) = the standard error.

The non statistical methodology utilized in the hourly comparisons, consisted of determining the number of times per complete tidal cycle that the computer model's speed or direction values were higher/lower or left/right of the hydraulic model values. These values were then computed as a percentage and a mean value for all catagories.

Once all station values both statistical and general, were calculated, these were grouped into four geographical areas (Table 1a; and Figure 2) and a quantitative set of values was determined for the region (Table 1b). The regional set of values consisted of: (1) a mean difference range; (2) the standard error range; (3) percentage range of computer values, high or low, left or right of the hydraulic model; (4) mean percentage of occurrences high/low, or left/right of the hydraulic model and (5) mean value for occurrance high/low or left/right of hydraulic model.

TABLE 1a
Geographical grouping of sampling stations in San Francisco Bay for analysis

STATIONS	BOUNDARIES	GENERAL DESCRIPTION
01-09	37.78° to 37.83°N 122.50° to 122.33°W	Entrance to San Francisco Bay
10-19	37.80° to 37.85°N 122.33° to 122.42°W	Area surrounding Yerba Beuna Islands

TABLE 1b

Regional values from statistical and general comparison between computerized and hydraulic model of San Francisco Bay. Speed in knots, *direction in degrees.*

STATION		MEAN DIFFERENCE RANGE SPEED (KNS)	MEAN DIFFERENCE RANGE DIRECTION (°T)	RANGE STANDARD ERROR SPEED (KNS)	RANGE STANDARD ERROR DIRECTION (°T)	RANGE PERCENTAGE DIFFERENCE COMPUTER VS HYDRAULIC MODEL (MEAN PERCENTAGE) SPEED HIGH	SPEED LOW	[MEAN VALUE KNS/°T] DIRECTION RIGHT	DIRECTION LEFT
March	01-09	-.68 to .74	-51.98 to -2.70	.30 to .51	17.60 to 45.20	19-88% (49%) [.74]	12-81% (51%) [-.88]	16-100% (79%) [61.58]	00.84% (21%) [-36.46]
	10-19	-.15 to .51	-74.11 to 11.70	.12 to .39	24.33 to 27.59	08-65% (38%) [.28]	35-92% (62%) [.44]	08-100% (76%) [62.27]	00-92% (24%) [-39.42]
	20-37	-.27 to .36	-32.78 to 110.23	.09 to .38	19.55 to 46.69	35-77% (57%) [.27]	23-65% (43%) [.54]	56-100% (93%) [47.86]	00-44% (07%) [-63.34]
	38-51	-.11 to .21	-61.29 to 13.84	.14 to 1.02	20.25 to 28.79	31-77% (51%) [.34]	23-69% (46%) [-.40]	85-100% (97%) [44.60]	00-15% (03%) [-64.14]
May	01-09	-.78 to .71	-56.50 to -2.70	.33 to .54	24.96 to 28.71	19-81% (46%) [.82]	19-81% (54%) [-.86]	20-96% (77%) [59.33]	04-80% (23%) [-67.25]
	10-19	-.15 to .46	-72.96 to 11.94	.06 to .42	24.83 to 29.69	19-73% (40%) [.31]	27-81% (60%) [-.44]	12-100% (76%) [62.67]	00-88% (24%) [-66.09]
	20-37	-.28 to .37	-32.78 to 10.92	.09 to .43	19.65 to 27.40	38-73% (53%) [.58]	27-62% (47%) [-.60]	27-100% (71%) [48.43]	00-73% (29%) [-55.45]

STATION	MEAN DIFFERENCE RANGE SPEED (KNS)	MEAN DIFFERENCE RANGE DIRECTION (°T)	RANGE STANDARD ERROR SPEED (KNS)	RANGE STANDARD ERROR DIRECTION (°T)	RANGE PERCENTAGE DIFFERENCE COMPUTER VS HYDRAULIC MODEL (MEAN PERCENTAGE) SPEED HIGH	SPEED LOW	[MEAN VALUE KNS/°T] DIRECTION RIGHT	DIRECTION LEFT
38-51	-.15 to .31	-54.06 to 13.84	.14 to .31	6.73 to 28.74	23-54% (43%) [.46]	46-77% (57%) [-.43]	44-100% (90%) [45.95]	00-56% (10%) [-68.39]
October 1-09	-.82 to .87	-50.02 to -7.38	.10 to .95	23.51 to 44.11	27-69% (50%) [1.18]	31-73% (50%) [-1.29]	31-96% (77%) [65.78]	04-69% (23%) [-85.62]
10-19	-.65 to .64	-74.76 to 9.66	.23 to 1.67	23.76 to 26.38	27-62% (43%) [.56]	38-73% (57%) [-.81]	13-96% (77%) [73.38]	04-87% (23%) [-107.63]
20-37	-.33 to .41	-26.50 to 49.15	.17 to .83	19.68 to 28.16	46-65% (55%) [.95]	35-54% (45%) [-1.0]	31-96% (62%) [51.15]	04-69% (38%) [-108.65]
38-51	-.76 to .32	-50.31 to 47.30	.25 to .71	21.19 to 28.38	35-58% (51%) [.71]	42-65% (49%) [-.79]	32-100% (81%) [50.13]	00-68% (18%) [-91.14]

zero, the shapes of the two curves could be completely different. Therefore, the Student's-t formula (equation 1) was used only to determine a mean difference and a standard error for each set of paired station data. The above noted values for each set of paired station data were determined using the Student's-t statistics evaluation program (comparison of population means) as contained in the library programs of Texas Instruments TI 58/59 programmable calculator (Applied Statistics, 1977). The program involved the use of the bivariate data entry program and a two sample test to calculate the individualized student-t values of each station, the difference of the means and then the standard deviation, which was adjusted to be the standard error. The equations utilized by this TI 58/59 program, as stated by Perterson (1973) are:

$$t = \frac{\bar{X}_1 - \bar{X}_2 - \mu}{\left(\frac{1}{N_1} + \frac{1}{N_2}\right)^{1/2} \underbrace{\left(\frac{\Sigma X_{1i}^2 - N_1 \bar{X}_1^2 + \Sigma X_{2i}^2 - N_2 \bar{X}_2^2}{N_1 + N_2}\right)}_{B}} \qquad (1)$$

where:

t = Student-t value with $n_1 + n_2 - 2$ degrees of freedom

$\bar{X}_1$ = 24 hour means for the computer generated currents/direction

$\bar{X}_2$ = 24 hour mean for the hydraulic model currents/direction

μ = hypothetical mean difference value; set at zero

N_1 = number of computer model observations

N_2 = number of hydraulic model observations

and $n_1 = n_2$

B = standard deviation

$\bar{X}_1 - \bar{X}_2$ = difference between the means

STATIONS	BOUNDARIES	GENERAL DESCRIPTION
20-37	37.83° to 38.06°N 122.48° to 122.29°W	Northeastern San Francisco Bay and San Pablo Bay
38-52	37.50° to 37.70°N 122.35° to 122.13°W	Southern San Francisco Bay

RESULTS

The statistical and general analysis values (Table 2) show that the two models differ significantly in the magnitude and direction of the tidal current vectors each produce. The range in the speed and direction mean differences were found to be approximately equal for the months of March and May for speed and all three months for direction, but they differed in magnitude region by region. The observed speed ranges were (largest to smallest range):

TABLE 2
Statistical and general analysis values for the four regions of Figure 2

REGION	MONTHS	VALUE RANGE IN KNOTS
I	All	-.82 to .87
III	March and May	-.28 to .37
	All	-.33 to .41
II	March and May	-.15 to .51
	All	-.65 to .64
IV	March and May	-.15 to .31
	All	-.76 to .32

The relative size of the overall range in the mean direction differences did not coincide with the speed distribution. Rather, the distributions from the largest to the smallest were:

TABLE 3
Variations in direction in the four regions of Figure 2

REGION	MONTHS	VALUE RANGE IN DEGREES
III	All	-32.78 to 110.03
IV	March and May	-61.29 to 13.84
	All	-61.29 to 47.30
II	All	-74.11 to 11.94
I	All	-56.50 to -2.70

To further expand how significant the mean difference values are, an examination of the overall range in the standard error is necessary. This gives some indication as to the agreement between a set of curve shapes and to the overall agreement between the two models. Examining the regions for speed, the greatest to the least range in standard error are:

TABLE 4
Variations of magnitude in the four regions of Figure 2

REGION	RANGE IN KNOTS
II	0.06 to 1.67
IV	0.14 to 1.02
I	0.10 to 0.95
III	0.09 to 0.83

The sequence of the standard error range for direction varied from the speed distributions as follows:

TABLE 5
The standard error range for direction in the four regions of Figure 2

REGION	RANGE IN DEGREES
I	17.60 to 45.20
III	19.55 to 46.69
IV	6.73 to 28.79
II	23.76 to 29.69

Even though these values appear to be small in magnitude, overall 0.09 to 1.02 knots (4.6 to 52.0 cm/sec) for speed and 6.73° to 46.69° for direction, they indicate that a significant disagreement in curve shapes or values exists. To more clearly determine how large the disagreement is between the computerized and the hydraulic model, the curve values were compared on an hour by hour basis. The results of Tables 4 and 5; are further summerized below as an overall percentage of occurrence and a mean value for a specific region to give a clearer picture of agreement/disagreement. These values were found to be:

TABLE 6
Percentage of high and low magnitude values relative to the mean
SPEED (KNOTS)

REGION	HIGH % OF OCCURRANCE	VALUE	LOW % OF OCCURRANCE	VALUE
I	48.33	0.91	51.67	-1.01
II	40.30	0.38	59.70	-0.56
III	55.00	0.60	45.00	-0.71
IV	48.33	0.50	51.67	-0.54

Percentage of left and right occurence relative to the mean
DIRECTION

REGION	RIGHT % OF OCCURRANCE	VALUE	LEFT % OF OCCURRANCE	VALUE
I	77.67	62.23	22.33	-63.11
II	76.33	66.11	23.67	-71.05
III	75.33	49.15	24.67	-75.81
IV	89.33	46.89	10.67	-71.21

It can be seen that speed is under predicted in Regions I, II, and IV over 50% of the time by 0.5 to 1.0 knots (25.5 to 51.479 cm/sec) and over predicted in Region III over 50% of the time by 0.6 knots (30.6 cm/sec). Where as, direction is predicted high or to the right of the observed values over 75% of the time by

values ranging from 49.15° to 66.11°. The speed curves show that the absolute value of the current magnitudes varied from .06 knots to 3.38 knots (3.1 to 172.4 cm/sec). Thus the predicted difference was high 18 to 100% depending on the magnitude of current vector. Since direction is not an increasing magnitude, the sector of agreement/disagreement ranged from 118.10° to 137.16° in width, which far out ways any usefulness.

DISCUSSION

The development of the computerized San Francisco Bay tidal current model was an attempt to create a quick access reference of the tidal current at any point or time in the Bay for application to Search and Rescue drift programs. The statistical and general comparisons of the tidal data produced by the model to the hydraulic model of the Army Corps of Engineers was an attempt to determine if the two data bases were comparable. The Bay hydraulic model was utilized as a reference source to simplify data collection (no ship time or current meters required) and analysis by eliminating any wind drift vectors produced in real world sampling.

The San Francisco Bay Hydraulic Model is driven by a repetitive 19 year mean tidal forcing function at the ocean entrance and comes to equilibrium throughout the Bay after spin-up. This allows for repetitive sampling of data curves, but does not match real world conditions since the real ocean entrance tidal curve is continually being modified by tidal constituents. To over come part of this problem, the ocean entrance curves were matched for tidal height (March and May) and tidal current speeds (October) and the assumption made that all other geographic locations may approach agreement. However, as seen by Table 1b, this was not the case. This can be seen in the large speed and direction disagreements. Another reason for this nonagreement is felt to be due to the fact that the computerized tidal current charts are based on a 1954 tidal current survey by the National Ocean Survey. Therefore, comparisons of a 1954 survey to 1977 tidal conditions, as modeled by the hydraulic model, should show disagreement. NOS is in the process of resurveying the Bay and plans for completion of field work in 1980.

CONCLUSIONS

The comparison between the data sets of the computerized tidal current model and the hydraulic San Francisco Bay Model revealed that a significant disagreement in speed and direction exists. It is recommended that the National Ocean Survey tidal current chart data be used with caution. The disagreement in the tidal current speed was found to be best represented by the hour by hour analysis, which showed the computer model underpredicting speeds and overpredicting direction. The speed values were underpredicted in magnitude in Regions I, II and IV over 50% of the time by from 0.5 to 1.0 knots (25.5 to 51.0 cm/sec) and overpredicted in Region III over 50% of the time by 0.6 knots (30.6 cm/sec). The underprediction of speed was found to be approximately 18% to 1000% of the magnitude of a current generated by the San Francisco Bay hydraulic model, another indication of significant disagreement. The direction values were predicted high or to the right of an observed value over 75% of the time for all regions by a value between 49.15° to 66.11°. The Coast Guard Oceanographic Unit is planning a field test of the accuracy and utility of the Army Corp of Engineers Hydraulic Model and the National Ocean Survey Tidal Current Charts as sources of tidal current information. Should this field test show the Hydraulic Model to be a superior source of tidal current data a new set of tidal current charts will be generated based on it.

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APPENDIX I

INSTRUCTIONS FOR RUNNING THE PROGRAM

The program LITSF and the current velocity by position grid are generally stored on disk. The following program is required to obtain the tidal current information from the tidal current program for Long Island Sound (See listing at the end of this section).

The first six cards are called the job control cards, utilized by the Coast Guard's CDC 3300 computer. They will remain unchanged for every job run.

Card LITS 1 is the station name and meridian card. It is always the same for Long Island Sound.

Card LITS 2 contains the permanent current indexing parameters and directions for Long Island Sound. These are entered in the following format: Columns. 1-6 Permanent current (PERMC) 3 decimals, Columns 7-8 IND1, Columns 9-10 IND2, Columns 11-12 IND3, Columns 13-14 IND4, Columns 15-16 IND5, Columns 17-18 IND6, Columns 19-22 Flood Direction (NFDIR), Columns 23-26 Ebb Direction (NEDIR). The function of each of the indexing parameters is given in Table 1 at the end of this section. Normally these indexing parameters are never changed.

Cards LITS 3-8 are the station constants which determine the amplitude and phase lag for the reference station. These constants are supplied by the National Ocean Survey Production Division and need not be changed. The constitutents are entered in the following format: Columns 1-4 station number, Columns 5-8 station card sequence number, Colums. 9-13 constituent amplitude (3 decimal places), Columns. 14-17 constituent epoch (1 decimal place), Columns 18-71 repitition of Columns 9-17.

Cards LITS 9-23 are the year constant cards. The format is given by Morgan, et al. 1975 is as follow: "Columns 1-4 year-example = 1979, Columns 5-6 year type identifer = 0 for a common year, = 1 for a leap year, Columns 7-8 year card sequence number, Columns 9-12 Node factor (f) for the first constituent, Columns 13-16 Greenwich V + u for the first constituent (0_h, Jan. 1), Columns 17-72 repititions of columns

9-16. Each year the node factor (f) and equilibrium argument (V + u) must be added for the following twenty six constants: M_2, S_2, N_2, K_1, M_4, O_1, M_6, $(MK)_3$, S_4, $(MN)_4$, ν_2, S_6, μ_2, $(2N)_2$, $(00)_1$, λ_2, S_1, M_1, J_1, Mm, Ssa, Sa, MSf, Mf, ρ, Q_1, T_2, R_2, $(2Q)_1$, P_1, $(2SM)_2$, M_3, L_2, $(2MK)_3$, M_8 and $(MS)_4$." These constituents are found in (Schureman 1958).

Card LITS 24 is the Date Control Card which is the first card which the user must supply. This card is to have the following format: Columns 1-2 month number, Columns 3-4 beginning day, Colums 5-6 ending day, Columns 7-72 repetition of the above as needed. The maximum period for a single calculation is 32 days. If the desired time periods are not consecutive, use individual date control cards in separate computer runs.

Card 25 is the Termination Control Card. This card determines if the tides will be calculated for one or more than one reference station or time. It has the following format: Columns 1-4 (MS) = 0. The new problem is for the same station; = 1. The new problem is for a different station, Columns 5-8 (MY) = 0. The new problem is for the same year; = 1. The new problem is for a different year, Columns 9-12 (MD) = 0. The new problem is for the same day; = 1. The new problem is for a different day. The job is terminated if all three cards are zero. This is the format which is always used in calculating tidal currents.

Card LITS 26 this card may be used to call for a listing of the tidal currents at the reference station for the period given in the Date Control Card. If this is desired a 1 is entered in column 1. If not a 0 is entered in column 1. When using the model to calculate tidal currents a 0 is entered in the column.

Cards 26-29 are repeated for each additional time or position for which a tidal vector is needed.

Cards LITS 30 is the last Month List card it is always blank.

Card LITS 31 is the final Day Count and Station I.D. card.

Card LITS 32 is the last position card. A latitude of 99 is entered in columns one and two. This signals the end of the input data cards.

The last two cards in the deck are the job termination control cards used in the Coast Guard's CDC 3300, they never change.

```
$JOB.GCOMT622.19995CSE.5.500
$SCHED.CORE=60.TIME=1.CLASS=C,R41=1(16).SCH=1
$*DEF(O..LITS.WKLYTMPF.LITS.01.CGOU.I)
$*DEF(O..1.WKLYTMPF.LITD.01.CGOU.I)
$MAP=N
$COMP.LITS
1       THE RACE, N.Y.     T.M. 75  W.
-00250 1 1 3 0 0 0 295 100
5781    10308224850052325840074322280020103040005212280011706 31
5781    2                                  001442263                  000991971
5781    3         000222531
5781    4                                          000230795000312586
5781    5         000670309                        000862742          001422580
5781    6000681495
1977    1103510181000000010352793 891 14110722036 822 85711103053 9231159
1977    2100000001072 2111035 25310000000103520281035 968 517126510353582
1977    310001800 8701986 64219861123182510002011100028051035 2582 6521104
1977    4 822  92 82226321000  2010001780 822 807100034951035258210541527
1977    51179 997 9561894 76320761149 47110351018
1977    6
1977    7
1977    8
1977    9
1977   10
1977   11
1977   12
1977   13
1977   14
1977   15
013131020101


2 1
4116 7147
0001.02.01.1977

2 1
4116 7147
0001.02.03.1977

2 1
4116 7147
0001.03.01.1977

1 1                                                                  LITS  27
99
$*DEF(C,W..U)
..
```

APPENDIX II

INSTRUCTIONS FOR RUNNING THE MODEL FOR SAN FRANCISCO BAY

The following small program is required to run the tidal current model for San Francisco Bay. The listing is identical to the Long Island Sound program for all job control cards, but exhibits necessary changes for program data and instructions.

The first six cards are called the job control cards. They will remain constant for every job run.

Card 1. Selects the reference tidal station and the time meridian longitude. It is always the same for San Francisco Bay.

Card 2. Contains the permanent current indexing parameters and directions for San Francisco Bay. The format used is the same as that used in the program for Long Island Sound (See Instructions For Running The Program For Long Island Sound Section).

Card 3-9. Are the station constants consisting of the amplitude and phase lag for each tidal forcing function at the reference station. The format is the same as that in the program for Long Island Sound.

Cards 9-23. Are the year constant cards. The format for these cards and method of determining these constituents is outlined in the section giving instructions for running the model for Long Island Sound.

Card 24. Is the date control card. Its purpose is to set the month(s), start and stop day that tidal currents are to be computed for. It has the same format as Card 24 for Long Island Sound (See Appendix I).

Card 25. Is the termination control card which is used to separate different reference stations and time controlled calculations. The format for this card is given in the section giving instructions for the running of the program for Long Island Sound.

Card 26. Is the month list card. This card specifies that a listing of the times of slack water maximum ebb and flood for the interval given on the date control card is to be printed. A one in column (1) causes only a listing to be printed. A zero causes the program to calculate the tidal current at the position of

Cards 25 and 26. Are used to consecutively run two or more differing tidal current information request for information at reference stations. They are normally blank when being used in operational work.

Card 27. Is the station ID and Day count card. The format and use of this card is described in Appendix I.

Card 28. Is the position card specifying the geographic position where tidal current information is required. The latitude is given to the nearest minute and the longitude to the nearest 0.25 minute. The format is given in the section on Long Island Sound.

Card 29. Is the date time card. This card inputs the date time group of the occurrence. Its format is given in the section on Long Island Sound.

The set of cards, 26-29. Are repeated for each additional time or position for which a tidal current vector is needed.

Card 30. Is the last month list card and is placed at the end of all series of time and position cards. It is always blank.

Card 31. Is the last day count and station ID card. It is formated the same as card 27.

Card 32. Is the final position card. A latitude of 99 degrees is always entered in columns 1 and 2. This signals the end of the data end put cards.

The final two cards are the job termination control cards, and are formated as shown. These two cards like the first six cards are always the same.

```
1       THE GOLDEN GATE CA     T.M. 122.5 W                                                           LITS    1
-00200 1 1 3 0 0 000650245                                                                           LITS    2
6229    1030303060006803060005702830008000420001603380006000360001200920 LITS    3
6229    2                                  001202950                         000602650 LITS    4
6229    30003004100004031l0                000300360000500370                  0602650 LITS    5
6229    4                                  00020022000100022000l001660          0602650 LITS    6
6229    50002001700025004 30                          000903290              001903000 LITS    7
6229    6                                                                               LITS    8
1979    1103630191000000010363019089000681073243808192969111218570922308 7LITS    9
1979    2100000001073243810362444100000001036244410363020051225301036179 4LITS   10
1979    3100018001361041806390049112400001000200110002801103605810647248 0LITS   11
1979    4081923940819297010000025100017750819294010003499103605811054092 8LITS   12
1979    50994130909552370076019421151127510363019                         LITS   13
1979    6                                                                 LITS   14
1979    7                                                                 LITS   15
1979    8                                                                 LITS   16
1979    9                                                                 LITS   17
1979   10                                                                 LITS   18
1979   11                                                                 LITS   19
1979   12                                                                 LITS   20
1979   13                                                                 LITS   21
1979   14                                                                 LITS   22
1979   15                                                                 LITS   23
082325


1 2
3749 1222500
0800

1 2
3749 1222500
0900

1 2
3749 1222500
1000

1 2
3749 1222500
1100

1 2
3749 1222500
1200

1 2
3749 1222500
1300

1 2
99
```

APPENDIX III

PRODUCTION OF THE TIDAL CURRENT FILES

The tidal current files are prepared using tidal current charts form the National Ocean Survey (NOS). The most recent charts should be used in making these files. The charts are available from the National Ocean Survey Office, Rockville, Maryland. The first step is the construction of a grid overlay for the tidal current chart. These are either done using a template or drawn in with pencil so that the lines lie on whole minutes of latitude and longitude.

A grid square measuring approximately 2 x 2 nautical miles has been found to work best. This grid size corresponds to a 2' x 3' along much of the U.S. coast line. A tidal current speed and direction is assigned to each grid square for the entire chart of currents. These values are either based on direction measurements or from interpolation. When an interpolated value is required, the speed and direction of the currents are assumed to change linearly with changes of equal value between each grid square. That is, if there are 5 blank grid squares between two observations, then the change from one block to the next will be 1/5 of the difference between the two observations. The same is true for the directions. An example is given below:

Observed						Observed
2.0 knots	1.8	1.6	1.4	1.2	1.0	0.8
180 T	185	190	195	200	205	210

The current is always assumed to parallel the coast line unless observed to do otherwise. Upon completion of each tidal chart the current values are transferred from the array set up to a computer listing with one computer card for each grid square. The cards have the following format:

Line 1-4. The latitude in degrees and minutes for the south east corner of the grid square.

Line 6-9. The longitude in degrees and minutes for the south east corner of the grid square.

Line 11-14. The speed in 10th of knots and direction in 10s of degrees for slack water at the reference station.

Line 16-19. The same as lines 11-14 for one hour after slack water at the reference station.

This sequence may be repeated for each interval of the tide up to 13 times. All multiples of 5 are to be left as blanks.

A program is produced by copying LISND and changing only the five character name to the first five characters in the name of the body of water being modeled.

```
$JOB.GCOMP622.19917ASE.1.50
$SCHED.CORE=39.SCR=2,CLASS=R,841=1(16)
$*DEF(R,,WKLYTMPF.LISND.01.CGOU.OU01.ALL)
$*DEF(A,,WKLYTMPF.LISND.01.CGOU.OU01.80.1000,,,,841.16)
$*DEF(O,,1.WKLYTMPF,LISND.01.CGOU.0)
$MAP=N
$FTNU(X)
      PROGRAM LISND                                                   LSND     1
      DIMENSION CUR(1000),MDIR(1000)
      INTEGER CUR
      INTEGER MDIR
      N=0
   50 READ(60,3) LAD,LAM,LOD,LOM,(CUR(I),MDIR(I),I=1,13),IAR
      WRITE(1,3) LAD,LAM,LOD,LOM,(CUR(I),MDIR(I),I=1,13),IAR
    3 FORMAT (I2,I2,I3,I2,1X,13(I2,I2,1X),I2)
      N=N+1
      IF (LOD .EQ. 999) GO TO 200
      GO TO 50
  200 WRITE (61,250)
  250 FORMAT (1H ,*DATA FOR LONG ISLAND SOUND ON DISC*)
      WRITE (61,350) N
  350 FORMAT (1H ,I5,* CARDS READ*)
      STOP
      END
         FINIS
$X.LGO
4114 7127 0133 0828 0828 0628 0628 0228 0110 0309 0608 1009 0409 0104 0130
4116 7127 0127 0628 0628 0728 0727 0428 0127 0308 0909 1009 0408 0509 0308
4118 7127 0127 0627 0728 0727 0728 0527 0127 0309 0609 0509 0409 0409 0207
4120 7127 0527 0628 0827 0228 0625 0416 0114 0209 0816 0412 0410 0309 0230
4106 7130 0329 1028 1530 1830 0627 0327 0216 0219 1514 0121 0120 0120 0125
4108 7130 0124 0000 0125 0323 0324 0324 0223 0224 0224 0223 0224 0124 0125
4110 7130 0433 0435 0434 0433 0234 0134 0217 0319 0317 0316 0216 0233 0220
4112 7130 0730 0830 0830 0630 0430 0130 0217 0417 0516 0416 0216 0230 0529
4114 7130 0233 0930 1029 0628 0629 0230 0110 0809 0506 1209 0806 0134 0433
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4102	7242	0427	0628	0927	0927	0728	0327	0106	0706	1006	0906	0706	0406	0208
4104	7242	0000	0526	0826	0826	0726	0326	0104	0705	1005	1005	0906	0705	0304
4106	7242	0106	0326	0726	0726	0725	0326	0106	0606	1005	1106	1006	0706	0405
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4102	7245	0229	0627	0827	0827	0627	0327	0106	0607	0807	0907	0708	0506	0108
4104	7245	0127	0526	0926	0926	0726	0326	0105	0506	0906	0906	0806	0606	0306
4106	7245	0000	0426	0826	0826	0725	0426	0106	0506	0906	1006	0906	0706	0306
4108	7245	0000	0326	0726	0826	0726	0427	0106	0506	0907	1006	0907	0707	0406
4110	7245	0227	0526	0826	0926	0726	0327	0106	0506	0907	0907	0808	0606	0307
4112	7245	0227	0827	1026	0927	0826	0326	0109	0706	0907	0908	0708	0506	0106
4114	7245	0129	0327	0627	0925	0424	0227	0109	0609	0409	0910	0408	0406	0110
4058	7248	0128	0528	0928	0629	0428	0127	0108	0408	0409	0709	0610	0308	0108
4100	7248	0129	0430	0529	0530	0330	0129	0108	0409	0609	0709	0610	0409	0108
4102	7248	0127	0527	0727	0728	0527	0328	0127	0408	0608	0808	0708	0508	0108
4104	7248	0226	0626	0925	1026	0825	0526	0125	0407	0707	0807	0706	0506	0207
4106	7248	0000	0526	0826	0926	0725	0526	0126	0406	0708	0908	0707	0606	0308
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4058	7251	0127	0527	0927	0828	0428	0128	0109	0409	0409	0809	0609	0308	0208
4100	7251	0128	0529	0628	0729	0529	0229	0108	0508	0808	0908	0708	0508	0208
4102	7251	0127	0527	0727	0727	0627	0328	0127	0408	0708	0808	0708	0507	0208
4104	7251	0126	0626	0826	0826	0726	0426	0125	0406	0707	0807	0706	0506	0207
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4100	7254	0127	0629	0828	1028	0729	0328	0108	0608	0908	1008	0808	0608	0208
4102	7254	0000	0527	0821	0628	0728	0328	0127	0507	0707	0908	0708	0607	0208
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4106	7254	0000	0427	0726	0727	0626	0327	0000	0406	0608	0807	0607	0506	0207
4108	7254	0127	0426	0728	0727	0626	0327	0000	0406	0608	0806	0607	0406	0206
4110	7254	0127	0326	0626	0526	0526	0227	0107	0406	0507	0706	0507	0407	0207
4112	7254	0130	0326	0333	0104	0435	0134	0108	0406	0508	0506	0411	0408	0107
4058	7257	0128	0728	1028	1128	0428	0328	0108	0608	0409	0909	0809	0310	0309
4100	7257	0128	0728	1028	1128	0928	0428	0107	0707	1008	1108	0908	0707	0308
4102	7257	0000	0528	0828	0628	0728	0328	0127	0506	0807	0908	0708	0606	0308
4104	7257	0000	0427	0627	0626	0527	0326	0000	0406	0606	0708	0607	0506	0307
4106	7257	0000	0427	0728	0727	0627	0327	0000	0406	0607	0707	0606	0506	0206
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4110	7257	0126	0327	0526	0426	0426	0226	0107	0406	0507	0606	0406	0306	0106
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4058	7300	0228	0529	0929	1127	0229	0130	0109	0409	0309	0810	0809	0208	0810
4100	7300	0102	0528	1028	1127	0928	0528	0108	0608	0908	1108	1008	0908	0508
4102	7300	0127	0627	0927	0827	0827	0428	0127	0408	0808	0908	0808	0607	0308
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4110	7300	0226	0424	0525	0424	0326	0124	0207	0408	0506	0507	0407	0208	0000
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4110	7303	0125	0425	0524	0424	0525	0122	0204	0408	0506	0505	0406	0203	0000
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4102	7306	0127	0728	1027	1127	0926	0626	0127	0308	0710	0908	0908	0708	0308
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4054	7309	0000	0206	0506	0103	0204	0106	0134	0325	0324	0226	0224	0000	0104
4056	7309	0100	0102	0503	0101	0202	0102	0133	0314	0502	0412	0316	0000	0301
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4056	7315	0108	0309	0307	0426	0128	0125	0127	0206	0208	0806	0104	0308	0209
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4104	7315	0227	0525	0926	0926	0825	0625	0226	0000	0406	0506	0406	0305	0107
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4104 7321 0130 0430 0524 0631 0625 0223 0123 0304 0505 0604 0407 0104 0214
4054 7324 0000 0319 0519 0619 0518 0318 0119 0334 0502 1035 0600 0502 0201
4056 7324 0107 0318 1027 1026 1024 0924 0120 0204 0804 1308 0604 1105 0706
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4052 7339 0706 0111 0318 0320 0322 0421 0323 0219 0100 0405 0204 0504 0202
4054 7339 0205 0000 0224 0424 0423 0423 0324 0000 0205 0506 0606 0505 0405
4056 7339 0304 0000 0625 0825 0825 0725 0426 0125 0403 0704 0804 0704 0504
4054 7342 0105 0125 0524 0625 0624 0424 0224 0000 0306 0406 0407 0406 0206
4056 7342 0106 0124 0524 0427 0228 0233 0000 0000 0103 0408 0506 0408 0308
4054 7345 0504 0105 0105 0204 0124 0224 0000 0000 0000 0000 0306 0206 0105
    999
$*DEF(C,,1)
$*DEF(M,W,WKLYTMPF,LISND,01,CGOU,OU01,,,,,,I,999999)
$*DEF(R,W,WKLYTMPF,LISND,01,CGOU,OU01,UNUSED)
,,
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$JOB,GCOMP622,19924ASE,1,50
$SCHED,CORE=40,TIME=1,CLASS=C,841=1(16),SCR=2
$*DEF(R,,CGOU-TAM,SANFR,01,CGAS,DP01,ALL)
$*DEF(A,,CGOU-TAM,SANFR,01,CGAS,DP02,80,1000,,,,841,16)
$*DEF(O,,1,CGOU-TAM,SANFR,01,CGAS,0)
$MAP=N
$FTNU(X,L)
      PROGRAM SANFRAN
      DIMENSION CUR(1000),MDIR(1000)
      INTEGER CUR
      INTEGER MDIR
      N=0
   50 READ(60,3) LAD,LAM,LOD,LOM,(CUR(I),MDIR(I),I=1,12),IAR
      WRITE(1,3) LAD,LAM,LOD,LOM,(CUR(I),MDIR(I),I=1,12),IAR
    3 FORMAT (I2,I2,1X,I3,I4,1X,12(I2,I2,1X),5X,I2)
      N=N+1
      IF (LOD .EQ. 999) GO TO 200
      GO TO 50
  200 WRITE (61,250)
  250 FORMAT (1H ,*DATA FOR SAN FRANCISCO ON DISK FILE*)
      WRITE (61,350) N
  350 FORMAT (1H ,I5,* CARDS READ*)
      WRITE(1,4)
    4 FORMAT(5X,3H999)
      STOP
      END
         FINIS
$X,LGO
3730 12205      332 1118 1718 1818 1518  918   32 1032 1832 2032 1732 1032          1
3732 12205      127  318  518  518  418  218  127  227  427  527  427  227          1
3730 122075000332 1109 1709 1809 1509  909   32 1032 1832 2032 1732 1032          1
3732 122075000233  614  914  914  814  514  133  533  933 1033  933  533          1
3734 122075000134  418  618  618  518  318  134  334  634  734  634  334          1
3736 122075000127  218  418  418  318  218  127  227  327  427  327  227          1
3730 12210      100  509  909  909  709  409  100  500  900 1000  800  500          1
3732 12210      332 1114 1714 1814 1514  914  132 1032 1832 2032 1732 1032          1
3734 12210      132  414  614  614  514  314  114  332  632  732  632  332          1
3736 12210      132  314  414  514  414  214  132  232  432  532  432  332          1
3738 12210      132  318  418  518  418  218  132  332  432  532  432  332          1
3740 12210      134  218  418  418  318  218  134  234  434  534  434  234          1
3742 12210      127  218  318  318  318  218  127  227  327  427  327  227          1
3732 122125000100  509  809  909  709  409  100  500  900 1000  800  500          1
3734 122125000331 1113 1713 1813 1613  913  131 1031 1831 2031 1731 1031          1
3736 122125000232  614  914  914  814  514  132  532  932 1032  832  532          1
3738 122125000132  414  614  614  514  314  132  332  632  732  632  332          1
3740 122125000132  314  514  414  314  214  132  332  432  532  332  232          1
3742 122125000127  312  412  512  412  212  127  327  427  527  427  227          1
3734 12215      231 1109 1809 1909 1609  909  131 1031 1631 1831 1631  931          1
3736 12215      232 1114 1714 1914 1614  914  132 1032 1832 1932 1632  932          1
3738 12215      134 1016 1516 1416 1116  616  234 1134 1734 1834 1334  534          1
3740 12215      416 1116 1216 1016  616  116  334 1334 1534 1334  734  134          1
3742 12215      332  614  714  714  414  114  232  732  832  732  432  132          1
3744 12215      218  418  518  418  318  118  227  527  627  527  327  127          1
3802 12215     2927 1627  227 1105 2005 2305 2005 1205  127 1627 2827 3227          1
3804 12215     2027 1027  127  811 1411 1611 1411  811  127 1027 1827 2127          1
3734 122175000130  509  909 1009  809  509  130  530  830  930  830  530          1
3736 122175000132 1214 1914 2014 1614  814  132 1232 1832 2032 1632  832          1
3738 122175000134 1216 1916 2016 1616  816  234 1234 1834 2034 1634  834          1
3740 122175000216 1116 1616 1816 1416  716  334 1334 1834 1934 1534  734          1
3742 122175000216 1216 1616 1516 1216  716  334 1334 1934 2134 1534  634          1
3744 122175000616 1216 1316 1116  716  116  434 1434 1634 1434  834  134          1
3746 122175000218  318  418  318  218  118  227  327  327  327  227  127          1
3750 122175000127  200  200  100  100    0  127  327  327  327  227  127          1
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3752	122175000127	118	218	218	218	118	127	127	227	327	227	227	1
3800	122175000827	427	127	400	600	600	400	200	127	527	827	1027	1
3802	122175002525	1125	107	1207	1807	1907	1607	807	525	1625	2625	2925	1
3804	122175001228	528	110	610	910	1010	810	410	110	828	1228	1428	1
3806	122175000227	118	218	218	318	218	118	127	227	327	427	327	1
3734	12220	0	109	209	209	209	109	0	100	200	200	200	100	1
3736	12220	114	414	514	514	414	214	100	200	300	600	500	300	1
3738	12220	216	916	1016	916	616	216	134	734	1234	1234	834	334	1
3740	12220	317	1017	1117	1017	717	317	235	835	1335	1335	935	435	1
3742	12220	818	1218	1818	1718	1318	418	500	1500	1900	1600	1100	600	1
3744	12220	417	1417	1917	1817	1317	717	535	1735	2135	2135	1735	735	1
3746	12220	316	1516	2016	1816	1516	1216	434	1534	2134	2234	1634	734	1
3748	12220	818	1918	2018	1818	1318	518	834	2534	3134	3034	2134	734	1
3750	12220	409	709	809	609	409	109	327	827	1027	827	527	127	1
3752	12220	222	204	404	604	604	404	204	222	422	722	622	422	1
3754	12220	127	118	218	218	218	118	118	127	227	327	227	227	1
3800	12220	327	127	109	209	309	309	309	109	127	327	427	427	1
3802	12220	2124	624	306	1206	1706	1706	1306	606	224	1624	2424	2624	1
3804	12220	222	204	304	404	404	304	204	122	322	522	522	422	1
3806	12220	220	102	202	302	302	202	102	120	220	320	320	220	1
3808	12220	118	127	227	227	227	127	127	118	218	218	218	218	1
3738	122225000118	209	209	209	109	109	100	100	200	200	100	100	1
3740	122225000118	218	218	218	118	118	100	100	200	200	100	100	1
3742	122225000118	218	218	218	118	118	104	104	204	204	104	104	1
3744	122225001316	916	1016	1016	816	116	500	1300	2000	1000	1400	716	1
3746	122225000516	1616	1916	1816	916	116	900	1800	2200	2100	1500	500	1
3748	122225000514	1614	2114	1914	1414	614	732	2132	2932	3032	2532	1232	1
3748	122237500209	1309	1609	1509	1109	409	1030	2030	2530	2430	1830	930	1
3749	122225000514	1314	1414	1314	1114	514	532	1532	2532	2832	1832	532	1
3749	122237500412	1312	1512	1412	1012	312	630	1630	2430	2630	1730	630	1
3750	122225000622	604	1104	1204	1104	604	632	1222	1522	1622	1322	922	1
3752	122225000418	300	700	1000	1000	700	400	418	1218	1418	1218	818	1
3754	122225001613	327	727	1027	1027	727	427	413	1213	1713	1613	1213	1
3758	122225000327	127	200	300	300	300	200	100	327	427	427	427	1
3800	122225002122	622	504	1304	1604	1504	1104	404	522	1722	2422	2622	1
3802	122225000420	302	702	802	802	602	302	120	720	1020	1020	820	1
3804	122225000418	400	800	900	800	700	400	118	818	1018	1018	818	1
3806	122225000418	400	800	900	800	700	400	118	818	1018	1018	818	1
3808	122225000418	0	0	0	0	0	0	118	818	1018	1018	818	1
3748	12225	309	1109	1309	1109	709	327	1027	2127	2427	2227	1627	727	1
3748	122262500209	909	909	609	309	427	1527	2327	2527	2327	1527	727	1
3749	12225	309	1309	1609	1509	1109	409	1027	2127	2427	2227	1727	727	1
3749	122262500226	1508	2608	2908	2608	1708	526	2126	3226	3726	3126	1826	1
3750	12225	726	508	908	808	608	308	533	1726	2326	2626	2326	1726	1
3750	122262500323	505	905	805	605	305	533	1623	2323	2323	2023	1423	1
3751	12225	227	309	409	409	309	109	227	427	627	727	627	327	1
3751	122262500103	1203	1903	2203	2003	1303	121	1021	1721	2021	1721	921	1
3752	12225	518	1004	1204	1204	904	404	418	1418	2118	2518	2318	1818	1
3754	12225	618	600	1400	1800	1700	800	800	218	1218	1818	1718	1318	1
3756	12225	718	200	1200	1800	2000	1600	900	218	1518	1818	2018	1718	1
3758	12225	2019	103	1203	2103	2303	2003	1203	219	1919	3119	3419	3019	1
3800	12225	620	502	1102	1402	1602	1502	802	320	1520	2020	2020	1820	1
3802	12225	620	502	1102	1402	1602	1502	802	320	1520	2020	2020	1820	1
3804	12225	315	533	833	933	833	733	433	315	915	915	915	815	1
3806	12225	209	227	427	527	427	327	227	109	309	509	509	409	1
3747	122287501300	700	300	427	827	1327	1327	1127	627	100	1400	1500	1
3748	122275000209	909	909	609	309	327	1627	2327	2527	2327	1627	727	1
3748	122287501024	1506	2806	3306	3006	1906	124	1624	3724	4524	4124	2724	1
3749	122275000508	2208	3008	3108	2508	1508	126	1026	1526	1426	1126	526	1
3749	122287500509	2209	3009	3109	2509	1409	124	1024	1524	1424	1124	524	1
3750	122275000306	1506	2206	2606	2206	1306	124	1024	1624	1624	1324	1024	1
3751	122275000135	435	435	435	235	135	119	419	519	519	319	119	1
3751	122287500100	100	100	100	100	100	109	109	109	109	109	109	1
3752	122275000033	33	33	33	33	33	118	218	218	218	218	118	1
~~3754~~	~~122275001009~~	~~100~~	~~800~~	~~900~~	~~700~~	~~300~~	~~809~~	~~2009~~	~~2109~~	~~1909~~	~~1509~~	~~1409~~	~~1~~
3756	122275001218	100	800	1200	1200	1000	500	218	1218	1818	2118	1618	1

```
3758 122275000318   104   304   404   404   304   204   118   318   518   618   518          1
3800 122275000415   527   827  1027  1127  1027   627   315  1015  1315  1315  1015          1
3802 122275000415   527   827  1027  1127  1027   627   315  1015  1315  1315  1015          1
3804 122275000118   200   400   500   400   300   200   118   418   418   418   318          1
3806 122275000409    27    27    27    27    27    27   209   709  1009  1109   609          1
3744 12230          400   900  1000   900   600   100   418  1118  1318  1218   818   318    1
3746 12230          400   700  1000   900   600   100   422  1122  1322  1222   822   322    1
3748 12230          822  1404  2604  3104  2804  1704   122  1522  3522  4322  3922  2522    1
3748 122312500822  1404  2604  3104  2804  1704   122  1522  3522  4322  3922  2522          1
3749 12230          709   209   627  1127  1127  1027   827   827   527   209   909  1009    1
3749 122312500712  1612  1812  1812  1412   912   112   727   927   727   527   127          1
3744 122325000423   905  1605  1505  1105   205   423  1323  2023  2023  1723  1123          1
3746 122325000423  1005  1605  1505  1105   205   423  1323  2023  2023  1723  1123          1
3748 122325000427  1409  2209  1709  1309   709   109   827  1027   727   327   127          1
3744 12235          121   803   903  1003   803   603   214  1021  1721  1521  1121   621    1
3746 12235          121   803   903  1003   803   603   212  1021  1721  1521  1121   721    1
3748 12235          121   803   903  1003   803   503   212  1021  1721  1521  1121   721    1
     999
$*DEF(C,,1)
$*DEF(M,W,CGOU-TAM,SANFR,01,CGAS,DP02,,,,,,I,999999)
$*DEF(R,,CGOU-TAM,SANFR,01,CGAS,DP02,UNUSED)
,,
```

APPENDIX IV

LISTING OF LITSF

```
$JOB,GCOMP622,19918FSE,3,1000
$SCHED,CORE=40,SCR=9,TIME=3,CLASS=C,B41=1(16)
$*DEF(R,W,CGOU-TAM,LITSF,01,CGAS,DP02,ALL)
$*DEF(A,,CGOU-TAM,LITSF,01,CGAS,DP02,1280,400,,,,B41,16)
$*DEF(O,W,LITS,CGOU-TAM,LITSF,01,CGAS,0)
$MAP=N
$FTNU(X=LITS,L)
      PROGRAM TIDALCUR                                                  LTSF
      DIMENSION A(37),AMP(37),EPOC(37),XODE(114),VPU(114),MO(13),SP(37),LTSF
     1NBDAY(13),NEDAY(13),XCOS(1025),SPD(37),ARG(37),TABHR(24),AKU(55), LTSF
     2ANG(37),KDAY(32),STORX(816),EXTIM(780),JXTIM(260),VEL(260),S(37), LTSF
     3EPOCH(37),AMPA(37),JJXTI(16),JSTIM(260),                          LTSF
     4IYR(15),NUM(15),ISTA(6),NO(6),JJSTI(10),XVEL(10)                  LTSF
      COMMON YVEL(10),JJJST(10)                                         LTSF
      DATA  TABHR/              -  24.,  720., 1392., 2136., 2856., 3600.,LTSF
     1    4320., 5064., 5808., 6528., 7272., 7992.,-  24.,  720., 1416.,LTSF
     2    2160., 2880., 3624., 4344., 5088., 5832., 6552., 7296., 8016./LTSF
      DATA  AKU/              7.5, 7.6, 7.6, 7.6, 7.7, 7.7, 7.8, 7.8, 7.8,LTSF
     1 7.9, 7.9, 8.0, 8.0, 8.0, 8.1, 8.1, 8.1, 8.2, 8.2, 8.2, 8.3, 8.3,LTSF
     2 8.4, 8.4, 8.4, 8.5, 8.5, 8.5, 8.6, 8.6, 8.7, 8.7, 8.7, 8.8, 8.8,LTSF
     3 8.8, 8.9, 8.9, 9.0, 9.0, 9.0, 9.1, 9.1, 9.2, 9.2, 9.2, 9.3, 9.3,LTSF
     4 9.3, 9.4, 9.4, 9.4, 9.5, 9.5, 9.6/                               LTSF
      DATA  A/                      28.9841042,  30.0000000,  28.4397295,LTSF
     1   15.0410686,  57.9682084,  13.9430356,  86.9523127,  44.0251729,LTSF
     2   60.0000000,  57.4238337,  28.5125831,  90.0000000,  27.9682084,LTSF
     327.8953548,16.1391017,29.4556253,15.0000000,14.4966939,           LTSF
     4   15.5854433,   0.5443747,   0.0821373,   0.0410686,   1.0158958,LTSF
     5    1.0980331,  13.4715145,  13.3986609,  29.9589333,  30.0410667,LTSF
     6   12.8542862,  14.9589314,  31.0158958,  43.4761563,  29.5284789,LTSF
     7   42.9271398,  30.0821373, 115.9364169,  58.9841042/              LTSF
      NNDAY=0                                                           LTSF
C       DEVELOP COSINE TABLE                                            LTSF
      H=.00153398                                                       LTSF
      B=2.0-H*H                                                         LTSF
      MART=64                                                           LTSF
      NART=0                                                            LTSF
      DO 35 I=1,16                                                      LTSF
      NART1=NART+1                                                      LTSF
      NART2=NART+2                                                      LTSF
      PART=NART                                                         LTSF
      PHIA=PART*H                                                       LTSF
      PHIB=PHIA+H                                                       LTSF
      XCOS(NART1)=COS(PHIA)                                             LTSF
      XCOS(NART2)=COS(PHIB)                                             LTSF
      MART1=MART-1                                                      LTSF
      DO 30 J=NART2,MART1                                               LTSF
      XCOS(J+1)=B*XCOS(J)-XCOS(J-1)                                     LTSF
   30 CONTINUE                                                          LTSF
      NART=MART                                                         LTSF
      MART=MART+64                                                      LTSF
   35 CONTINUE                                                          LTSF
      XCOS(1025)=0.0                                                    LTSF
      MS=1                                                              LTSF
      MY=1                                                              LTSF
      MD=1                                                              LTSF
      CON=1024./90.                                                     LTSF
      DO 90 J=1,37                                                      LTSF
      A(J)=A(J)*CON                                                     LTSF
   90 CONTINUE                                                          LTSF
      NCO=0                                                             LTSF
   95 NSEQ=1                                                            LTSF
      IF (MS) 120,120,110                                               LTSF
  110 READ 550                                                          LTSF
```

```
      READ 532, PERMC,IND1,IND2,IND3,IND4,IND5,IND6,NFDIR,NEDIR
      READ 531, ISTA(1),NO(1),(AMP(J),EPOC(J),J=1,7),ISTA(2),NO(2),
     1(AMP(J),EPOC(J),J=8,14),ISTA(3),NO(3),(AMP(J),EPOC(J),J=15,21),
     2ISTA(4),NO(4),(AMP(J),EPOC(J),J=22,28),ISTA(5),NO(5),(AMP(J),
     3EPOC(J),J=29,35),ISTA(6),NO(6),(AMP(J),EPOC(J),J=36,37)
      DO 115 L=1,5
      IF (ISTA(L) .NE. ISTA(L+1)) GO TO 451
  115 CONTINUE
      ISTA1=ISTA(1)
      DO 118 L=1,6
      IF (NO(L) .NE. L) GO TO 450
  118 CONTINUE
  120 IF (MY) 131,131,125
  125 READ 533, IYR(1),LY1,NUM(1),(XODE(J),VPU(J),J=1,8),IYR(2),LY2,
     1NUM(2),(XODE(J),VPU(J),J=9,16),IYR(3),LY3,NUM(3),(XODE(J),VPU(J),
     2J=17,24),IYR(4),LY4,NUM(4),(XODE(J),VPU(J),J=25,32),IYR(5),LY5,
     3NUM(5),(XODE(J),VPU(J),J=33,40),IYR(6),LY6,NUM(6),(XODE(J),VPU(J),
     4J=41,48),IYR(7),LY7,NUM(7),(XODE(J),VPU(J),J=49,56),IYR(8),LY8,
     5NUM(8),(XODE(J),VPU(J),J=57,64),IYR(9),LY9,NUM(9),(XODE(J),VPU(J),
     6J=65,72),IYR(10),LY10,NUM(10),(XODE(J),VPU(J),J=73,80),IYR(11),
     7LY11,NUM(11),(XODE(J),VPU(J),J=81,88),IYR(12),LY12,NUM(12),
     8(XODE(J),VPU(J),J=89,96),IYR(13),LY13,NUM(13),(XODE(J),VPU(J),
     9J=97,104),IYR(14),LY14,NUM(14),(XODE(J),VPU(J),J=105,112),IYR(15),
     1LY15,NUM(15),(XODE(J),VPU(J),J=113,114)
      DO 127 L=1,14
      IF (IYR(L) .NE. IYR(L+1)) GO TO 452
  127 CONTINUE
      DO 130 L=1,15
      IF (NUM(L) .NE. L) GO TO 453
  130 CONTINUE
      IYR0=MOD(IYR(1),100)
      IYR1=IYR(1)
  131 IF (MD) 160,160,140
  140 READ 534, (MO(J),NBDAY(J),NEDAY(J),J=1,12)
C        SET UP TABLES FOR NO-ZERO CONSTITUENTS
      NBDY=NBDAY(1)
      MO1=MO(1)
      NEDY=NEDAY(1)
  160 K=0
      DO 180 J=1,37
      IF (AMP(J)) 180,180,170
  170 K=K+1
      AMPA(K)=AMP(J)*XODE(J)
      TEMX=VPU(J)-EPOC(J)
      IF (TEMX .GE. 0.) GO TO 171
      TEMX=TEMX+360.
  171 EPOCH(K)=TEMX*CON
      SPD(K)=A(J)
      SP(K)=SPD(K)/10.
      S(K)=SPD(K)/60.
  180 CONTINUE
      NOCON=K
C        OPERATING TABLES NOW STORED AS AMPA(K),EPOCH(K),SPD(K)
      DO 4000 JP=1,12
      IF (MO(JP)) 4005,4005,185
  185 MO(13)=MO(JP)
      NBDAY(13)=NBDAY(JP)
      NEDAY(13)=NEDAY(JP)
      NNEDA=NEDAY(13)+1
      NODAYS=NEDAY(13)-NBDAY(13)+2
      NOHRS=NODAYS*24
      IF (MO(13) .NE. 12) GO TO 190
      NOHRS=NOHRS+24
  190 HRS=NOHRS
C        DETERMINE FIRST HOUR OF TIME PERIOD
      IF (LY1) 200,200,210
```

```
  200 K=MO(13)
      GO TO 215
  210 K=MO(13)+12
  215 BDAY=NBDAY(13)
      FIRST=TABHR(K)+BDAY*24.
      NFIRST=FIRST
      DO 220 J=1,816
      STORX(J)=0.
  220 CONTINUE
C      CURRENT=PERMC+AMPA(K)*COS(A(K)*T+EPOCH(K))
      KOUNT=0
      KT=0
      DO 380 K=1,NOHRS
      IF (KOUNT .GT. 0) GO TO 260
      KOUNT=1
  231 DO 250 J=1,NOCON
      ARGU=SPD(J)*FIRST+EPOCH(J)
      ARG(J)=AMOD(ARGU,4096.)
  250 CONTINUE
      GO TO 290
  260 DO 280 J=1,NOCON
      ARG(J)=ARG(J)+SPD(J)
  270 IF (ARG(J) .LT. 4096.) GO TO 280
      ARG(J)=ARG(J)-4096.
      GO TO 270
  280 CONTINUE
  290 DO 374 J=1,NOCON
      IF (ARG(J)-1024.) 320,320,300
  300 IF (ARG(J)-2048.) 350,350,310
  310 IF (ARG(J)-3072.)360,360,330
  320 ANG(J)=ARG(J)
      GO TO 340
  330 ANG(J)=4096.-ARG(J)
  340 NP=ANG(J)+1.5
      STORX(K)=STORX(K)+AMPA(J)*XCOS(NP)
      GO TO 374
  350 ANG(J)=2048.-ARG(J)
      GO TO 370
  360 ANG(J)=ARG(J)-2048.
  370 NP=ANG(J)+1.5
      STORX(K)=STORX(K)-AMPA(J)*XCOS(NP)
  374 CONTINUE
      IF (K .NE. NOHRS) GO TO 380
      IF (KT .EQ. 1) GO TO 378
      FIRST=FIRST+HRS-1.
      KT=1
      CHECK=STORX(K)
      STORX(K)=0.
      GO TO 231
  378 CKSUM=CHECK-STORX(K)
  380 CONTINUE
      IF (IND4 .NE. 1) GO TO 395
      DO 385 K=1,NOHRS
      IF (STORX(K)) 381,385,382
  381 NEF=0
      STORX(K)=STORX(K)*(-1.0)
      GO TO 383
  382 NEF=1
  383 STORX(K)=SQRT(STORX(K))
      IF (NEF .EQ. 1) GO TO 385
      STORX(K)=STORX(K)*(-1.0)
  385 CONTINUE
  395 DO 400 K=1,NOHRS
      STORX(K)=STORX(K)+PERMC
  400 CONTINUE
      GO TO (419,401,401),IND1
```

```
  401 KDAY(I)=NHDAY(13)
      NODAYS=NODAYS-1
      DO 410 I=2,NODAYS
      KDAY(I)=KDAY(I-1)+1
  410 CONTINUE
      PRINT 550
      PRINT 555, IYR1,MO(13),CKSUM,NEDIR,NEDIR
      PRINT 556
      PRINT 537, (KDAY(I),STORX(24*I-23),STORX(24*I-22),STORX(24*I-21),
     1STORX(24*I-20),STORX(24*I-19),STORX(24*I-18),STORX(24*I-17),
     2STORX(24*I-16),STORX(24*I-15),STORX(24*I-14),STORX(24*I-13),
     3STORX(24*I-12),KDAY(I),STORX(24*I-11),STORX(24*I-10),
     4STORX(24*I-9),STORX(24*I-8),STORX(24*I-7),STORX(24*I-6),
     5STORX(24*I-5),STORX(24*I-4),STORX(24*I-3),STORX(24*I-2),
     6STORX(24*I-1),STORX(24*I),I=1,NODAYS)
  419 IF (INDI .EQ. 3) GO TO 4000
      ITEMS=0
      EXTIM(1)=4000.
      K=1
      NST=1
      NOHRS=NOHRS-1
      IJOB=1
      DO 3000 I=1,NOHRS
      GO TO (1038,1055),IJOB
 1038 GO TO (1039,2576,2621,2681,2691),NST
 1039 TIME=NFIRST*10
 1040 NHR=0
      NWHOA=1
      NARC=1
      GO TO 1060
 1050 TIME=(NFIRST+I-2)*10
      NHR=0
 1055 NARC=1
 1060 STOXR=0.
      GO TO (1075,1100),NARC
 1075 DO 1090 J=1,NOCON
      IF (NHR .EQ. 1) GO TO 1076
      ARGU=SP(J)*TIME+EPOCH(J)
      GO TO 1089
 1076 ARGU=S(J)*TIME+EPOCH(J)
 1089 ARG(J)=AMOD(ARGU,4096.)
 1090 CONTINUE
      GO TO 1120
 1100 DO 1110 J=1,NOCON
      IF (NHR .EQ. 1) GO TO 1101
      ARG(J)=ARG(J)+SP(J)
      GO TO 1105
 1101 ARG(J)=ARG(J)+S(J)
 1105 IF (ARG(J) .LT. 4096.) GO TO 1110
      ARG(J)=ARG(J)-4096.
      GO TO 1105
 1110 CONTINUE
 1120 DO 1220 J=1,NOCON
      IF (ARG(J)-1024.) 1150,1150,1130
 1130 IF (ARG(J)-2048.) 1180,1180,1140
 1140 IF (ARG(J)-3072.) 1190,1190,1160
 1150 ANG(J)=ARG(J)
      GO TO 1170
 1160 ANG(J)=4096.-ARG(J)
 1170 NP=ANG(J)+1.5
      STOXR=STOXR+AMPA(J)*XCOS(NP)
      GO TO 1220
 1180 ANG(J)=2048.-ARG(J)
      GO TO 1200
01190 ANG(J)=ARG(J)-2048.
 1200 NP=ANG(J)+1.5
```

```
      STOXR=STOXR-AMPA(J)*XCOS(NP)
 1220 CONTINUE
      IF (IND4 .NE. 1) GO TO 1225
      IF (STOXR) 1221,1225,1223
 1221 NEF=0
      STOXR=STOXR*(-1.0)
      GO TO 1224
 1223 NEF=1
 1224 STOXR=SQRT(STOXR)
      IF (NEF .EQ. 1) GO TO 1225
      STOXR=STOXR*(-1.0)
 1225 STOXR=STOXR+PERMC
      GO TO (2500,2505,2510,2710,2692,2684,2682,2693,2715),NWHOA
 2500 NWHOA=2
      NARC=2
      P1=STOXR
      GO TO 1060
 2505 NWHOA=3
      P2=STOXR
      GO TO 1060
 2510 P3=STOXR
      IF (P1) 2515,2520,2525
 2515 IF (P2) 2530,2535,2575
 2520 IF (P2) 2545,2550,2544
2525  IF (P2) 2620,2565,2570
 2530 IF (P1-P2) 2575,2580,2585
 2535 IF (P2-P3) 2543,2595,2595
 2543 TIME=TIME+1.
 2544 JSW=1
      GO TO 2731
 2545 JSW=2
      GO TO 2731
 2550 IF (P3) 2670,2600,2685
 2561 TIME=TIME+1.
      GO TO 2545
 2565 IF (P2-P3) 2605,2605,2561
 2570 IF (P1-P2) 2610,2625,2620
 2575 JSW=1
      NSW=2
      NST=2
      NFOE=1
 2576 IF (STORX(I)) 2577,2630,2630
 2577 IF (STORX(I)-STORX(I+1)) 2999,2640,2640
 2580 IF (P2-P3) 2660,2600,2670
 2585 IF (P2-STORX(I+1)) 2675,2675,2680
 2595 JSW=2
      NSW=2
 2596 TIME=(TIME+1.)*6.-3.
 2597 EXTIM(K)=4000.
      EXTIM(K+3)=4000.
      GO TO 2902
 2600 TIME=TIME+1.
      GO TO 1040
 2605 JSW=1
      NSW=1
      GO TO 2596
 2610 IF (P2-STORX(I+1)) 2690,2695,2695
 2620 JSW=2
      NSW=1
      NST=3
      NFOE=2
 2621 IF (STORX(I)) 2630,2630,2623
 2623 IF (STORX(I)-STORX(I+1)) 2700,2700,2999
 2625 IF (P2-P3) 2695,2600,2705
 2630 NWHOA=4
      GO TO 1050
```

```
2640 NWHOA=5
     JSW=2
2641 EXTIM(K)=4000.
     EXTIM(K+3)=4000.
2642 IF (MO(13) .NE. 1) GO TO 1050
     IF (I .NE. 1) GO TO 1050
     TIME=NFIRST*10
     NBR=0
     GO TO 1055
2660 JSW=3
     NSW=1
2661 TIME=NFIRST*60
     GO TO 2902
2670 JSW=2
     NSW=2
     TIME=NFIRST*60
     GO TO 2597
2675 TIME=TIME+2.
     POINT1=P2
     JSW=3
     NSW=1
     NWHOA=6
     IJOB=2
     NBR=0
     GO TO 3000
2680 NWHOA=7
     JSW=3
     NSW=1
     NST=4
2681 IF (STORX(I)-STORX(I+1)) 2642,2642,2999
2682 NWHOA=6
2683 POINT1=STOXR
     NARC=2
     TIME=TIME+1.
     GO TO 1060
2684 IF (POINT1-STOXR) 2900,2686,2740
2685 JSW=1
     NSW=1
     TIME=NFIRST*60
     GO TO 2597
2686 OTIME=TIME
     TIME=TIME*6.-6.
     GO TO 2902
2690 NWHOA=5
     JSW=4
     NSW=2
     NST=5
2691 IF (STORX(I)-STORX(I+1)) 2999,2642,2642
2692 NWHOA=8
     GO TO 2683
2693 IF (POINT1-STOXR) 2740,2686,2900
2695 TIME=TIME+2.
     POINT1=P2
     JSW=4
     NSW=2
     NWHOA=8
     IJOB=2
     NBR=0
     GO TO 3000
2700 NWHOA=7
     JSW=1
     GO TO 2641
2705 JSW=4
     NSW=2
     GO TO 2661
2710 NWHOA=9
```

```
      POINT1=STOXR
      NARC=2
      TIME=TIME+1.
      GO TO 1060
 2715 IF (STOXR .EQ. 0.) GO TO 2730
      GO TO (2720,2725),NEOF
 2720 IF (STOXR .GT. 0.) GO TO 2755
 2721 TIME=TIME+1.
      POINT1=STOXR
      GO TO 1060
 2725 IF (STOXR .LT. 0.) GO TO 2755
      GO TO 2721
 2730 IF (NBR .EQ. 1) GO TO 2735
 2731 EXTIM(K)=TIME*6.
      GO TO 2995
 2735 EXTIM(K)=TIME
      GO TO 2995
 2740 TIME=TIME+1.
      POINT1=STOXR
      GO TO 1060
 2755 IF (NBR .EQ. 0) GO TO 2760
      NBR=0
      GO TO 2735
 2760 NBR=1
      NWHOA=4
      TIME=(TIME-1.)*6.
      GO TO 1055
 2900 OTIME=TIME
      TIME=TIME*6.-9.
 2902 AM=0.
      DO 2980 L=1,7
      STOX=0.
      IF (L .GT. 1) GO TO 2915
      DO 2910 J=1,NOCON
      ARGU=S(J)*TIME+EPOCH(J)
      ARG(J)=AMOD(ARGU,4096.)
 2910 CONTINUE
      GO TO 2930
 2915 DO 2925 J=1,NOCON
      ARG(J)=ARG(J)+S(J)
 2920 IF (ARG(J) .LT. 4096.) GO TO 2925
      ARG(J)=ARG(J)-4096.
      GO TO 2920
 2925 CONTINUE
 2930 DO 2950 J=1,NOCON
      IF (ARG(J) - 1024.) 2935,2935,2932
 2932 IF (ARG(J) - 2048.) 2943,2943,2933
 2933 IF (ARG(J) - 3072.) 2944,2944,2940
 2935 ANG(J)=ARG(J)
      GO TO 2941
 2940 ANG(J)=4096.-ARG(J)
 2941 NP=ANG(J)+1.5
      STOX=STOX+AMPA(J)*XCOS(NP)
      GO TO 2950
 2943 ANG(J)=2048.-ARG(J)
      GO TO 2945
 2944 ANG(J)=ARG(J)-2048.
 2945 NP=ANG(J)+1.5
      STOX=STOX-AMPA(J)*XCOS(NP)
 2950 CONTINUE
      IF (IND4 .NE. 1) GO TO 2955
      IF (STOX) 2951,2955,2953
 2951 NEF=0
      STOX=STOX*(-1.)
 2953 NEF=1
      GO TO 2954
```

```
2954 STOX=SQRT(STOX)
     IF (NEF .EQ. 1) GO TO 2955
     STOX=STOX*(-1.)
2955 STOX=STOX+PERMC
     IF (L .EQ. 1) SAVIT=STOX
     GO TO (2960,2956),NSW
2956 IF (SAVIT .GE. STOX) GO TO 2980
     GO TO 2962
2960 IF (SAVIT .LE. STOX) GO TO 2980
2962 SAVIT=STOX
     AM=L-1
2980 CONTINUE
     EXTIM(K+1)=TIME+AM
     EXTIM(K+2)=SAVIT
     IF (K .EQ. 1) GO TO 2990
     IF (EXTIM(K+1) .GT. EXTIM(K-2)) GO TO 2990
     TIME=OTIME+1.
     POINT1=STOXR
     GO TO 1055
2990 K=K+3
     ITEMS=ITEMS+3
2995 GO TO (2690,2680,2575,2620),JSW
2999 IJOB=1
3000 CONTINUE
     IF (IND5) 3081,3081,3075
3075 JITEM=ITEMS-3
     DO 3080 K=1,JITEM,3
     IF (EXTIM(K+2) .GE. .05) GO TO 3080
     IF (EXTIM(K+2) .LE. -.05) GO TO 3080
     EXTIM(K)=4000.
     EXTIM(K+3)=4000.
3080 CONTINUE
3081 KAY=ITEMS/3
     J=0
     DO 3150 K=1,ITEMS,3
     KL=K
     J=J+1
     M=0
     IF (EXTIM(KL) .NE. 4000.) GO TO 3105
     JSTIM(J)=4000
     GO TO 3106
3105 JHRS=EXTIM(KL)
     JDAY=MOD(JHRS,1440)
     JHR=JDAY/60
     JMIN=MOD(JDAY,60)
     IF (M .EQ. 1) GO TO 3110
     JSTIM(J)=JHR*100+JMIN
3106 KL=KL+1
     M=1
     GO TO 3105
3110 JXTIM(J)=JHR*100+JMIN
     VEL(J)=EXTIM(K+2)
     IF (VEL(J)) 3115,3150,3150
3115 IF (VEL(J) .LE. -.05) GO TO 3150
     VEL(J)=VEL(J)*(-1.)
3150 CONTINUE
     KK=KAY
     IF (JP .EQ. 1) GO TO 3170
     IF (JXTIM(1)-NSAV) 3152,3155,3160
3152 KA=KAY-1
     DO 3153 KO=1,KA
     JSTIM(KO)=JSTIM(KO+1)
     JXTIM(KO)=JXTIM(KO+1)
     VEL(KO)=VEL(KO+1)
3153 CONTINUE
     GO TO 3170
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3155 JSTIM(I)=NSAVS
     GO TO 3170
3160 JSTIM(KK+1)=JSTIM(KK)
     JXTIM(KK+1)=JXTIM(KK)
     VEL(KK+1)=VEL(KK)
     KK=KK-1
     IF (KK .EQ. 0) GO TO 3165
     GO TO 3160
3165 JSTIM(1)=4000
     JXTIM(1)=NSAV
     VEL(1)=SAV
3170 NDAY=NRDAY(13)
     NCOUNT=0
     NNJ=1
     K=1
     GO TO (3174,3174,3178),IND2
3174 PRINT 550
     PRINT 555,IYR1,MO(13),CKSUM,NEDIR,NEDIR
     PRINT 575
3178 IF (IND5 .EQ. 1) GO TO 3185
     KAYK=KAY-1
     DO 3180 J=1,KAYK
     IF (VEL(J) .GT. .25) GO TO 3180
     IF (VEL(J) .LT. -.25) GO TO 3180
     JSTIM(J)=4000
     JSTIM(J+1)=4000
3180 CONTINUE
3185 IF (IND6) 3200,3200,3186
3186 DO 3193 I=1,KAY
     IF (VEL(I) .GE. 12.95) GO TO 3191
     IF (VEL(I) .LE. -12.95) GO TO 3192
     IF (VEL(I) .GE. 7.55) GO TO 3187
     IF (VEL(I) .GT. -7.55) GO TO 3193
     TEMP=VEL(I)*(-1.)
     LPN=1
     GO TO 3188
3187 TEMP=VEL(I)
     LPN=2
3188 N=TEMP*10.0-74.5
     GO TO (3189,3190),LPN
3189 VEL(I)=AKU(N)*(-1.)
     GO TO 3193
3190 VEL(I)=AKU(N)
     GO TO 3193
3191 VEL(I)=9.6
     GO TO 3193
3192 VEL(I)=-9.6
3193 CONTINUE
3200 DO 3350 I=1,KAY
     IF (JSTIM(I) .LT. 4000) GO TO 3215
3210 IF (JXTIM(I) .GT. JXTIM(I+1)) GO TO 3250
     JJSTI(K)=9999
     JJXTI(K)=JXTIM(I)
     XVEL(K)=VEL(I)
     GO TO 3310
3215 IF (JXTIM(I) .LT. JSTIM(I)) GO TO 3210
     IF (JXTIM(I) .GT. JXTIM(I+1)) GO TO 3230
     JJSTI(K)=JSTIM(I)
     JJXTI(K)=JXTIM(I)
     XVEL(K)=VEL(I)
     GO TO 3310
3230 JJSTI(K)=JSTIM(I)
     JJXTI(K)=JXTIM(I)
     XVEL(K)=VEL(I)
     IF (JSTIM(I+1) .EQ. 4000) GO TO 3260
     IF (JXTIM(I) .GT. JSTIM(I+1)) GO TO 3260
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      GO TO 3300
 3250 IF (JSTIM(I+1) .EQ. 4000) GO TO 3255
      IF (JXTIM(I) .GT. JSTIM(I+1)) GO TO 3290
      GO TO 3295
 3255 JJSTI(K)=9999
      JJXTI(K)=JXTIM(I)
      XVEL(K)=VEL(I)
 3260 NLAST=NNJ+NCOUNT
      GO TO (3264,3264,3265),IND2
 3264 PRINT 585, NDAY,(JJSTI(J),JJXTI(J),XVEL(J),J=1,K)
      IF (IFLG .EQ. 1) GO TO 7502
      IBC=1
 7502 DO 7500 L=1,5
      JJJST(IBC)=JJSTI(L)
      YVEL(IBC)=XVEL(L)
      IBC=IBC+1
 7500 CONTINUE
 7504 IFLG=1
      IF (IND2 .EQ. 1) GO TO 3275
 3265 JK=K+1
      DO 3266 N=JK,5
      JJSTI(N)=9999
      JJXTI(N)=9999
      XVEL(N)=99.9
 3266 CONTINUE
      IF (IND3 .EQ. 3) GO TO 3267
      IF (IND3 .EQ. 1) GO TO 3268
 3267 CONTINUE
 3268 NSEQ=NSEQ+1
      IF (K .GT. 5 .AND. IND2 .EQ. 3) GO TO 3288
 3275 NNJ=NLAST+1
      NCOUNT=0
      K=1
      NDAY=NDAY+1
      NNDAY=NNDAY+1
      IF (NDAY .NE. NNEDA) GO TO 3350
      IF (MO(13) .NE. 12) GO TO 3287
      IF (NDAY .NE. 32) GO TO 3287
      PRINT 550
      PRINT 565, IYR1,ISTA1
      PRINT 580
      PRINT 585, NDAY,(JSTIM(J),JXTIM(J),VEL(J),J=NNJ,KAY)
 3287 NSAVS=JSTIM(I+1)
      NSAV=JXTIM(I+1)
      SAV=VEL(I+1)
      GO TO 4000
 3288 PRINT 570
      NNLAS=NLAST+1
      PRINT 595,ISTA1,MO(13),NDAY,IYR1,(JSTIM(J),JXTIM(J),VEL(J),
     1 J=NNJ,NNLAS)
      GO TO 3275
 3290 JJSTI(K)=9999
      JJXTI(K)=JXTIM(I)
      XVEL(K)=VEL(I)
      GO TO 3260
 3295 JJSTI(K)=9999
      JJXTI(K)=JXTIM(I)
      XVEL(K)=VEL(I)
 3300 K=K+1
      JJSTI(K)=JSTIM(I+1)
      JJXTI(K)=9999
      XVEL(K)=99.9
      GO TO 3260
 3310 NCOUNT=NCOUNT+1
      K=K+1
 3350 CONTINUE
```

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 4000 CONTINUE
 4005 READ 538,MS,MY,MO
      IF (MS+MY+MO) 4020,4020,95
 4020 CALL SLACK(JJJST,YVEL,NNDAY,NBDY,MO,IYR1,NEDY)
      IF(NNDAY .NE. 0) GO TO 4020
      STOP
  450 PRINT 501
      STOP
  451 PRINT 502
      STOP
  452 PRINT 503
      STOP
  453 PRINT 504
      STOP
  501 FORMAT(27H STATION CARDS OUT OF ORDER)
  502 FORMAT(31H STATION NUMBERS NOT CONSISTENT)
  503 FORMAT(28H YEAR NUMBERS NOT CONSISTENT)
  504 FORMAT(24H YEAR CARDS OUT OF ORDER)
  531 FORMAT(2I4,F5.3,F4.1,F5.3,F4.1,F5.3,F4.1,F5.3,F4.1,F5.3,F4.1,
     1F5.3,F4.1,F5.3,F4.1)
  532 FORMAT(F6.3,6I2,2I4,54X)
  533 FORMAT(I4,2I2,F4.3,F4.1,F4.3,F4.1,F4.3,F4.1,F4.3,F4.1,
     1F4.3,F4.1,F4.3,F4.1,F4.3,F4.1,F4.3,F4.1)
  534 FORMAT(36I2,8X)
  537 FORMAT(I9,12F9.1)
  538 FORMAT(3I4)
  550 FORMAT(80H
     1
  555 FORMAT(/32H PREDICTED TIDAL CURRENT    YEAR,I5,8H   MONTH,I3,12H
     1  CHECKSUM,F12.7/17H FLOOD DIRECTION,,I4,7H  TRUE,,15X18HEBB (-) D
     2IRECTION,,I4,7H  TRUE,/28H NOAA, NATIONAL OCEAN SURVEY/)
  556 FORMAT(27H HOURLY VELOCITIES IN KNOTS/7X111HDAY   HOURS    HOURS
     1   HOURS     HOURS     HOURS     HOURS     HOURS     HOURS     HOURS
     2HOURS     HOURS     HOURS/14X103H0/12      1/13      2/14      3/15
     3 4/16      5/17      6/18      7/19      8/20      9/21     10/22     11/
     423/)
  565 FORMAT(/35H PREDICTIONS BEGINNING DECEMBER 32,,I5,5X10HSTA. NO. ,
     1I4/)
  570 FORMAT(///23H   TROUBLE DAY FOLLOWS /)
  575 FORMAT(5X111HSLACK    MAXIMUM   SLACK    MAXIMUM   SLACK    MAXIMU
     1M   SLACK    MAXIMUM   SLACK    MAXIMUM   SLACK    MAXIMUM/,5X111H
     2WATER    CURRENT   WATER    CURRENT   WATER    CURRENT   WATER
     3CURRENT   WATER    CURRENT   WATER    CURRENT/118H DAY  TIME  TIME
     4  VELOC  TIME  TIME  VELOC  TIME  TIME  VELOC  TIME  TIME  VELOC
     5TIME  TIME  VELOC  TIME  TIME  VELOC/118H      H.M.  H.M.  KNOTS
     6H.M.  H.M.  KNOTS  H.M.  H.M.  KNOTS  H.M.  H.M.  KNOTS  H.M.  H.M
     7.  KNOTS  H.M.  H.M.  KNOTS)
  580 FORMAT(119H DAY  TIME  TIME  VELOC  TIME  TIME  VELOC  TIME  TIME
     1  VELOC  TIME  TIME  VELOC  TIME  TIME  VELOC  TIME  TIME  VELOC)
  585 FORMAT(1H0,I3,6(I6,I6,F7.2)/4X,6(I6,I6,F7.2)/4X,6(I6,I6,F7.2))
  590 FORMAT(I2,I4,3I2,5(I4,I4,F5.1),I3)
  595 FORMAT(15H     STA. NO.  ,I4,10H   MONTH  ,I2,8H   DAY  ,I2,9H
     1 YEAR  ,I4//6X6(I6,I6,F7.1)/6X6(I6,I6,F7.1))
      END
      SUBROUTINE SLACK (JSLAK,CEL,NNDAY,NBDY,MO,IYR1,NEDY)
      DIMENSION CUR(12),MDIR(12),JHR(10),JMIN(10)
      DIMENSION JSLAK(10),CEL(10)
      INTEGER DAYCONT
C  CUR(12)  - CURRENT SPEEDS IN KNOTS AND
C  MDIR(12) - ASSOCIATED CURRENT DIRECTIONS IN DEGREES TRUE FOR
C  1/12TH OF TIDAL CYCLE,6 EACH FOR EBB AND FLOOD.
C  AT DESIRED LOCATION IN POSITION MATRIX.
C  JSLAK(10) - TIMES OF SLACK WATER (ZONE TIME) FOR EITHER ONE OR
C  TWO DAYS OF THE YEAR (PASSED FROM MAIN PROGRAM).
C  CEL(10) - CURRENT SPEEDS IN KNOTS ASSOCIATED WITH TIMES OF MAXIMUM
C  FLOW.
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C  JHR(10) AND JMIN(10) - ARRAYS USED IN CALCULATION OF NUMBER OF HOURS
C  OF OCCURRENCE BEFORE OR AFTER CLOSEST SLACK WATER TIME (JSLAK)
      READ (60,797) MONLIST
      READ (60,797) DAYCONT,IDISC
  797 FORMAT (I1,1X,I1)
      IF(DAYCONT.EQ.2) NBDY=NEDY
C  READ POSITION OF OCCURRENCE
      IF (IDISC.EQ.1) GO TO 4199
      READ(60,13) ILAD,ILAM,ILOD,ILOM
   13 FORMAT (I2,I2,1X,I3,I4)
      IF (ILAD .EQ. 99) GO TO 94
      GO TO 4089
 4199 READ(60,4013) ILAD,ILAM,ILOD,ILOM
 4013 FORMAT(I2,I2,I3,I2)
      IF (ILAD .EQ. 99) GO TO 94
C  READ TIME AND DATE OF OCCURRENCE
 4089 READ(60,1) NHR,NMIN
    1 FORMAT(I2,I2)
      IF (MONLIST.EQ.1) GO TO 93
      NTIME=NHR*100+NMIN
      DO 8 K=1,10
      JHR(K)=JSLAK(K)/100
    8 JMIN(K)=JSLAK(K)-(JHR(K)*100)
      IF (DAYCONT.EQ.1) NNDAY=1
      IF(DAYCONT.EQ.2) NNDAY=2
      K=5*NNDAY-4
C  DETERMINE TIME OF SLACK WATER CLOSEST TO TIME OF OCCURRENCE
    5 IF (JSLAK(K).EQ.9999.AND.NTIME.GT.JSLAK(K+1)) GO TO 800
      IF (NTIME .GT. JSLAK(K) .AND. NTIME .LT. JSLAK(K+1) .AND. JSLAK
     1(K+1) .NE. 9999) GO TO 700
      IF (JSLAK(K)   .EQ. 9999 .AND. NTIME .LT. JSLAK(K+1)) GO TO 700
      IF (NTIME .GE. JSLAK(K) .AND. JSLAK(K+1) .EQ. 9999) GO TO 700
      IF (NTIME .GT. JSLAK(K) .AND. JSLAK(K+1) .EQ. 0)  GO TO 700
      IF (JSLAK(K).GT.NTIME) GO TO 700
      GO TO 800
  700 IF (JSLAK(K).EQ.9999.OR.JSLAK(K).GT.NTIME) K=K-1
      IF (JSLAK(K).EQ.0) K=K-1
      KKK=K
      KSLAK=JSLAK(K)/100
      XSLAK=KSLAK*100.
      YSLAK=JSLAK(K)-XSLAK
      ZSLAK=YSLAK/60.
      TSLAK=KSLAK+ZSLAK
      IF (JSLAK(K+1).EQ.9999) K=K+1
      IF (JSLAK(K+1).EQ.0) GO TO 701
      KSLAK=JSLAK(K+1)/100
      XSLAK=KSLAK*100.
      YSLAK=JSLAK(K+1)-XSLAK
      ZSLAK=YSLAK/60.
      TTSLAK=KSLAK+ZSLAK
      IF (JSLAK(K+1).LT.JSLAK(K)) TTSLAK=TTSLAK+24.
  702 TSPAN=TTSLAK-TSLAK
      GO TO 703
  701 IF (JSLAK(K+2).EQ.9999) K=K+1
      KSLAK=JSLAK(K+2)/100
      XSLAK=KSLAK*100.
      YSLAK=JSLAK(K+2)-XSLAK
      ZSLAK=YSLAK/60.
      TTSLAK=KSLAK+ZSLAK
      TTSLAK=TTSLAK+24.
      GO TO 702
  703 PERCOL=TSPAN/6.
      GO TO 20
  800 K=K+1
      IF (K.GT.(NNDAY*5)) GO TO 95
      GO TO 5
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   20 K=KKK
      XMIN=NMIN/60.
      XNTIME=NHR+XMIN
      IF (JSLAK(K).GT.NTIME) XNTIME=XNTIME+24.
      HRAFT=XNTIME-TSLAK
      XJJ1=HRAFT
C  DETERMINE FACTOR BY WHICH CURRENT SPEEDS AT DESIRED LOCATION ARE
C  TO BE MULTIPLIED TO GET ACTUAL CURRENT
      IF (CEL(K).EQ.99.9) K=K+1
      IF (CEL(K).EQ.0.) K=K+1
      IF (CEL(K) .GT. 0.) GO TO 122
      IF (IDISC.EQ.2) GO TO 500
C  CORRECTIONS FOR THE RACE  LONG ISLAND SOUND
      IF (ABS(CEL(K)) .GE. 1.8 .AND. ABS(CEL(K)) .LT. 2.2) FAC= .5
      IF (ABS(CEL(K)) .GE. 2.2 .AND. ABS(CEL(K)) .LT. 2.6) FAC= .6
      IF (ABS(CEL(K)) .GE. 2.6 .AND. ABS(CEL(K)) .LT. 3.0) FAC= .7
      IF (ABS(CEL(K)) .GE. 3.0 .AND. ABS(CEL(K)) .LT. 3.4) FAC= .8
      IF (ABS(CEL(K)) .GE. 3.4 .AND. ABS(CEL(K)) .LT. 3.8) FAC= .9
      IF (ABS(CEL(K)) .GE. 3.8 .AND. ABS(CEL(K)) .LT. 4.2) FAC=1.0
      IF (ABS(CEL(K)) .GE. 4.2 .AND. ABS(CEL(K)) .LT. 4.6) FAC=1.1
      IF (ABS(CEL(K)) .GE. 4.6 .AND. ABS(CEL(K)) .LT. 5.0) FAC=1.2
      IF (ABS(CEL(K)) .GE. 5.0 .AND. ABS(CEL(K)) .LT. 5.4) FAC=1.3
      GO TO 4
  500 CONTINUE
C  CORRECTIONS FOR THE GOLDEN GATE
      IF (ABS(CEL(K)).GT.0.0.AND. ABS(CEL(K)).LT.0.7) FAC=0.0
      IF (ABS(CEL(K)).GE.0.7.AND. ABS(CEL(K)).LT.1.2) FAC=0.2
      IF (ABS(CEL(K)).GE.1.2.AND. ABS(CEL(K)).LT.1.6) FAC=0.3
      IF (ABS(CEL(K)).GE.1.6.AND. ABS(CEL(K)).LT.2.1) FAC=0.4
      IF (ABS(CEL(K)).GE.2.1.AND. ABS(CEL(K)).LT.2.5) FAC=0.5
      IF (ABS(CEL(K)).GE.2.5.AND. ABS(CEL(K)).LT.3.0) FAC=0.6
      IF (ABS(CEL(K)).GE.3.0.AND. ABS(CEL(K)).LT.3.4) FAC=0.7
      IF (ABS(CEL(K)).GE.3.4.AND. ABS(CEL(K)).LT.3.9) FAC=0.8
      IF (ABS(CEL(K)).GE.3.9.AND. ABS(CEL(K)).LT.4.3) FAC=0.9
      IF (ABS(CEL(K)).GE.4.3.AND. ABS(CEL(K)).LT.4.8) FAC=1.0
      IF (ABS(CEL(K)).GE.4.8.AND. ABS(CEL(K)).LT.5.2) FAC=1.1
      IF (ABS(CEL(K)).GE.5.2.AND. ABS(CEL(K)).LT.5.7) FAC=1.0
      IF (ABS(CEL(K)).GE.5.7.AND. ABS(CEL(K)).LT.6.1) FAC=1.3
      IF (ABS(CEL(K)).GE.6.1.AND. ABS(CEL(K)).LT.6.6) FAC=1.4
      IF (ABS(CEL(K)).GE.6.6.AND. ABS(CEL(K)).LT.7.1) FAC=1.5
      GO TO 14
  122 IF (IDISC.EQ.2) GO TO 501
C  CORRECTIONS FOR THE RACE  LONG ISLAND SOUND
      IF (ABS(CEL(K)) .GE. 1.2 .AND. ABS(CEL(K)) .LT. 1.6) FAC= .4
      IF (ABS(CEL(K)) .GE. 1.6 .AND. ABS(CEL(K)) .LT. 1.9) FAC= .5
      IF (ABS(CEL(K)) .GE. 1.9 .AND. ABS(CEL(K)) .LT. 2.3) FAC= .6
      IF (ABS(CEL(K)) .GE. 2.3 .AND. ABS(CEL(K)) .LT. 2.6) FAC= .7
      IF (ABS(CEL(K)) .GE. 2.6 .AND. ABS(CEL(K)) .LT. 2.9) FAC= .8
      IF (ABS(CEL(K)) .GE. 2.9 .AND. ABS(CEL(K)) .LT. 3.3) FAC= .9
      IF (ABS(CEL(K)) .GE. 3.3 .AND. ABS(CEL(K)) .LT. 3.6) FAC=1.0
      IF (ABS(CEL(K)) .GE. 3.6 .AND. ABS(CEL(K)) .LT. 4.0) FAC=1.1
      IF (ABS(CEL(K)) .GE. 4.0 .AND. ABS(CEL(K)) .LT. 4.3) FAC=1.2
      IF (ABS(CEL(K)) .GE. 4.3 .AND. ABS(CEL(K)) .LT. 4.6) FAC=1.3
      GO TO 4
  501 CONTINUE
C  CORRECTIONS FOR THE GOLDEN GATE
      IF (ABS(CEL(K)).GT.0.0.AND. ABS(CEL(K)).LT.0.5) FAC=0.0
      IF (ABS(CEL(K)).GE.0.5.AND. ABS(CEL(K)).LT.0.9) FAC=0.2
      IF (ABS(CEL(K)).GE.0.9.AND. ABS(CEL(K)).LT.1.2) FAC=0.3
      IF (ABS(CEL(K)).GE.1.2.AND. ABS(CEL(K)).LT.1.5) FAC=0.4
      IF (ABS(CEL(K)).GE.1.5.AND. ABS(CEL(K)).LT.1.9) FAC=0.5
      IF (ABS(CEL(K)).GE.1.9.AND. ABS(CEL(K)).LT.2.2) FAC=0.6
      IF (ABS(CEL(K)).GE.2.2.AND. ABS(CEL(K)).LT.2.5) FAC=0.7
      IF (ABS(CEL(K)).GE.2.5.AND. ABS(CEL(K)).LT.2.9) FAC=0.8
      IF (ABS(CEL(K)).GE.2.9.AND. ABS(CEL(K)).LT.3.2) FAC=0.9
      IF (ABS(CEL(K)).GE.3.2.AND. ABS(CEL(K)).LT.3.5) FAC=1.0
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      IF (ABS(CEL(K)).GE.3.5.AND. ABS(CEL(K)).LT.3.8) FAC=1.1
      IF (ABS(CEL(K)).GE.3.8.AND. ABS(CEL(K)).LT.4.2) FAC=1.2
      IF (ABS(CEL(K)).GE.4.2.AND. ABS(CEL(K)).LT.4.5) FAC=1.3
      IF (ABS(CEL(K)).GE.4.5.AND. ABS(CEL(K)).LT.4.8) FAC=1.4
      IF (ABS(CEL(K)).GE.4.8.AND. ABS(CEL(K)).LT.5.2) FAC=1.5
C  FIND DESIRED LOCATION WITH CURRENT SPEEDS AND DIRECTIONS FOR
C  12 HOUR PERIOD
   14 READ(1,103)LAD,LAM,LOD,LOM,(CUR(I),MDIR(I),I=1,12),IAR
  103 FORMAT(I2,I2,1X,I3,I4,1X,12(F2.1,I2,1X),5X,I2)
      IF (LOD .EQ. 999) GO TO 93
      IF(37.EQ.ILAD)GO TO 104
  104 IF(ILAM.GE.48.AND.ILAM.LE.50)GO TO 105
      GO TO 114
  105 IF(ILOM.GE.2250.AND.ILOM.LT.3250)GO TO 106
      GO TO 114
  106 KLOM=LOM+125
      KLAM=LAM+1
      IF(LOD.EQ.ILOD)GO TO 136
      GO TO 14
  136 IF(ILOM.GE.LOM.AND.ILOM.LT.KLOM)GO TO 137
      GO TO 14
  137 IF(LAD.EQ.ILAD)GO TO 139
      GO TO 14
  139 IF(ILAM.GE.LAM.AND.ILAM.LT.KLAM)GO TO 25
      GO TO 14
  114 LLOM=LOM+250
      LLAM=LAM+2
      IF(LOD.EQ.ILOD)GO TO 116
      GO TO 14
  116 IF(ILOM.GE.LOM.AND.ILOM.LT.LLOM)GO TO 117
      GO TO 14
  117 IF(LAD.EQ.ILAD) GO TO 119
      GO TO 14
  119 IF(ILAM.GE.LAM.AND.ILAM.LT.LLAM) GO TO 25
      GO TO 14
C  FIND DESIRED LOCATION WITH CURRENT SPEEDS AND DIRECTIONS FOR
C  13 HOUR PERIOD IN LONG ISLAND SOUND
    4 READ(1,3)LAD,LAM,LOD,LOM,(CUR(I),MDIR(I),I=1,13),IAR
    3 FORMAT(I2,I2,I3,I2,1X,13(F2.1,I2,1X),I2)
      IF(LOD.EQ.999)GO TO 93
      JLOM=LOM+3
      JLAM=LAM+2
      IF (LOD .EQ. ILOD) GO TO 6
      GO TO 4
    6 IF (ILOM .GE. LOM .AND. ILOM .LT. JLOM) GO TO 7
      GO TO 4
    7 IF (LAD .EQ. ILAD) GO TO 9
      GO TO 4
    9 IF (ILAM .GE. LAM .AND. ILAM .LT. JLAM) GO TO 4025
      GO TO 4
 4025 WRITE (61,4026)
 4026 FORMAT (1H0,15X,*CURRENT SPEEDS FOR EACH HOUR OF THE CURRENT*)
      WRITE(61,4027) (CUR(I),I=1,13)
 4027 FORMAT(1H0,13(F4.1,2X))
      XJJ1=XJJ1/PERCOL
      XJJ1=XJJ1+.5
      JJ1=XJJ1
      IF (CEL(K)    .LT. 0.) GO TO 4040
      IF (JJ1 .NE. 0) JJ1=JJ1+1
      IF (JJ1.GT.6) JJ1=6
      IF (JJ1 .EQ. 0) JJ1=1
      IF (JSLAK(K).EQ.9999) GO TO 4099
      IF (JSLAK(K+1).EQ.9999) GO TO 4099
 4099 IF (CUR(JJ1) .EQ. 0.0) GO TO 100
      FCUR=CUR(JJ1)*FAC
      NDIR=MDIR(JJ1)*10
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      GO TO 4050
 4040 JJ2=JJ1+7
      IF (JJ2.GT.13) JJ2=13
      IF (CUR(JJ2) .EQ. 0.0) GO TO 100
      FCUR=CUR(JJ2)*FAC
      NDIR=MDIR(JJ2)*10
 4050 K=KKK
      IF (IDISC.EQ.2) GO TO 52
      WRITE(61,4051) MO,NBDY,IYR1,NTIME,JSLAK(K),FCUR,NDIR,ILAD,ILAM,
     1ILOD,ILOM,FAC
 4051 FORMAT(1H0,3HON ,I2,1H/,I2,1H/,I4,4H AT ,I4,", WITH SLACK WATER AT
     1 THE RACE AT ",I4,1H,,/," THE CURRENT VELOCITY IS ",F4.2,10
     2H KNOTS AT ,I3,* DEGREES AT POSITION *,I2,1X,I2,2HN,,1X,I3,1X,I2,2
     3HW,* FACTOR IS *,F3.1)
      GO TO 93
   25 WRITE (61,26)
   26 FORMAT (1H0,15X,*CURRENT SPEEDS FOR EACH HOUR OF THE CURRENT*)
      WRITE(61,27) (CUR(I),I=1,12)
   27 FORMAT(1H0,12(F4.1,2X))
      XJJ1=XJJ1/PERCOL
      XJJ1=XJJ1+.5
      JJ1=XJJ1
      IF (CEL(K)    .LT. 0.) GO TO 40
      IF (JJ1 .NE. 0) JJ1=JJ1+1
      IF (JJ1.GT.6) JJ1=6
      IF (JJ1 .EQ. 0) JJ1=1
      IF (JSLAK(K).EQ.9999) GO TO 99
      IF (JSLAK(K+1).EQ.9999) GO TO 99
   99 IF (CUR(JJ1) .EQ. 0.0) GO TO 100
      FCUR=CUR(JJ1)*FAC
      NDIR=MDIR(JJ1)*10
      GO TO 50
   40 JJ2=JJ1+7
      IF (JJ2.GT.12) JJ2=12
      IF (CUR(JJ2) .EQ. 0.0) GO TO 100
      FCUR=CUR(JJ2)*FAC
      NDIR=MDIR(JJ2)*10
   50 K=KKK
      IF (IDISC.EQ.2) GO TO 52
      WRITE(61,51) MO,NBDY,IYR1,NTIME,JSLAK(K),FCUR,NDIR,ILAD,ILAM,
     1ILOD,ILOM,FAC
   51 FORMAT(1H0,3HON ,I2,1H/,I2,1H/,I4,4H AT ,I4,", WITH SLACK WATER AT
     1 THE RACE AT ",I4,1H,,/," THE CURRENT VELOCITY IS ",F4.2,10
     2H KNOTS AT ,I3,* DEGREES AT POSITION *,I2,1X,I2,2HN,,1X,I3,1X,I2,2
     3HW,* FACTOR IS *,F3.1)
      GO TO 93
   52 WRITE(61,53) MO,NBDY,IYR1,NTIME,JSLAK(K),FCUR,NDIR,ILAD,ILAM,
     1ILOD,ILOM,FAC
   53 FORMAT(1H0,3HON ,I2,1H/,I2,1H/,I4,4H AT ,I4,", WITH SLACK WATER AT
     1 THE GOLDEN GATE AT ",I4,1H,,/," THE CURRENT VELOCITY IS ",F4.2,10
     2H KNOTS AT ,I3,* DEGREES AT POSITION *,I2,1X,I2,2HN,,1X,I3,1X,I4,2
     3HW,* FACTOR IS *,F3.1)
      GO TO 93
  100 WRITE(61,101) ILAD,ILAM,ILOD,ILOM,NTIME
  101 FORMAT(1H0,*THERE IS NO CURRENT AT POSITION *,/,
     1I3,1X,I2,2HN,,1X,I3,1X,I4,1HW,* AT *,I4)
   93 REWIND 1
      RETURN
   94 NNDAY = 0
      RETURN
      END
          FINIS
$*DEF(C,,LITS)
$*DEF(M,,CGOU-TAM,LITSF,01,CGAS,DP02,,,,,,I,999999)
$*DEF(R,,CGOU-TAM,LITSF,02,CGAS,DP02,UNUSED)
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